APPENDIX A
Fire Monitoring Handbook (Sheet 4) Monitoring Type Description Sheets

FMH-4 MONITORING TYPE DESCRIPTION SHEET
Grand Canyon National Park

Monitoring Type Code: FPIPO1D09

Monitoring Type Name: South Rim Ponderosa Pine (PIPO)

Prepared by: Tonja Opperman and Ken Kerr

Date: December 18, 1999, Updated 11/24/00

PHYSICAL DESCRIPTION
Located at 6000 to 7500 feet elevation on the South Rim on level to rolling terrain, including all aspects. Soils are moderately shallow with a silty loam texture. All are derived from Kaibab limestone parent material. Occasional barren rock outcrops.

BIOLOGICAL DESCRIPTION
Total overstory[1] stems are 50-100% *Pinus ponderosa*. *Pinus edulis*, *Juniperus osteosperma*, and *Quercus gambelli* may be present. Absolute canopy cover is 20-60%. The understory is a mix of the same overstory species. Common shrubs include *Artemisia tridentata*, *Gutierrezia sarothrae*, and *Pershia m*exicana. Common herbaceous plants include *Bouteloua gracilis*, *Poa fendlariana*, and *Lupinus* spp.

REJECTION CRITERIA
Large rock outcroppings or areas >20% of the plot with <10% ground cover; areas with anomalous vegetation, boundary fences; areas within 30 meters of roads, utility corridors, human-created trails, human-created clearings, or slash piles; areas burned within past 10 years; areas within 10 meters of significant historic or prehistoric sites or transitional ecotones. Areas with greatest amount of basal area contained in a species other than ponderosa pine.

DESIRED FUTURE CONDITION
At this time a literature search has been initiated to determine the desired future condition of ponderosa forests at Grand Canyon National Park, but it is not complete. Preliminary research suggests that there were anywhere from 14-18 overstory trees per acre (35-44 trees/ha) during pre-settlement and ponderosa pine comprised over 90% of the basal area, with the remainder occupied by pinyon, juniper, and Gambel oak (Covington 1994, Covington et al. 1998). Usually crown cover was less than 25% with trees clumped in groups of 2-44 individuals (Woolsey 1911, White 1985). All size classes were typically represented, but it was not a continuous pattern—trees were arranged in distinct size groups due to a number of decades between regeneration events (White 1985).
Frequent openings occurred, dominated by grasses and other herbaceous plants. Total fuel loads were typically 2 to 8 tons/acre (5-20 tons/ha) with averages estimated from 0.2 to 9.3 tons/acre (0.5-23 tons/ha) (Covington 1992, Covington 1994, Harrington and Sackett 1992). A postburn increase in fuel loads is acceptable after the initial prescribed fire treatments.

BURN PRESCRIPTION
Units will be burned during the growing, transition, and dormant seasons with head, flanking, and backing fires as needed to meet burn objectives. Units may be burned at six-year intervals for up to three consecutive treatments or until a Desired Future Condition is met. Prescription element ranges and treatment objectives were developed using past experience, BEHAVE program, and FOFEM program.

Fire Prescription Elements	
RH = 10-80%	Live Fuel Moisture = n/a
Dry Bulb = 40-80 F	Average Flame Length = 1-10 feet
Average Mid-flame Winds=0-15mph G30mph	Average Rate of Spread = 1-40 chs/hour

[1] Overstory trees are defined in the Fire Monitoring program as trees with a diameter at breast height of 15 cm (6 in) or greater. This definition does not take individual tree dominance or crown position into account.

10-hour TLFM = 3-15%	1000-hour TLFM = 9-25%

MONITORING VARIABLES IN ORDER OF IMPORTANCE
1. Overstory density
2. Fuel Load
3. Pole density

PRESCRIBED FIRE PROJECT OBJECTIVES—First Entry Burn
Immediately Post-Burn:
1. Reduce total fuel load by at least 30% on average, as measured over the landscape immediately post-burn (fuel reduction efforts will continue until the Desired Future Condition of 0.2-9.3 tons/acre is achieved).
2. Limit crown scorch to 30% on *Pinus ponderosa* with dbh greater than or equal to 16" (40 cm).

Two Years Post-Burn:
1. Reduce *Pinus ponderosa* poles with dbh of 1-6 inches (2.5-15 cm) to average 0-200 trees/acre (0-494 trees/ha). *This is a conservative target and more research is needed to define a better pole density target; there are currently 0-730 poles/ac (0-1800 poles/ha) of* Pinus ponderosa *in this size class*.

Five Years Post-Burn
1. Achieve and maintain a five-year post-burn density of 19-25 trees/acre of *Pinus ponderosa* in the 16"+ size class.

PRESCRIBED FIRE PROJECT OBJECTIVES—Second Entry Burn
Objectives will be written for this section, once results from first entry burn are known.

PRESCRIBED FIRE PROJECT OBJECTIVES—Third Entry Burn
Objectives will be written for this section, once results from first and second entry burns are known.

FIRE MONITORING OBJECTIVES
1. Install enough plots to be 80% confident that overstory ponderosa pine density figures are within 20% of the true population mean.
2. Install enough plots to be 80% confident that total fuel load estimates are within 20% of the true population mean.
3. With less than 30 plots, estimate pole densities with the most confidence possible. At this time over 70 plots are needed to monitor poles due to a high variation in the preburn pole densities.

DATA ANALYSIS
See FMH-4 Data Analysis Checklist

Literature Cited

Covington, W.W. and M.M. Moore. 1992. Postsettlement changes in natural fire regimes: implications for restoration of old-growth ponderosa pine forest. *In* Old-growth forests in the Southwest and Rocky Mountain regions: proceedings of a workshop, p. 81-99. USDA For. Serv. Gen. Tech. Rep. RM-213. 201p.

Covington, W.W. and M.M. Moore. 1994. Southwestern ponderosa pine forest structure. J. For. 39-47.

Covington, W.W., M.M. Moore, P.Z. Fule, H.B. Smith. 1998. Grand Canyon Forest Ecosystem Restoration Report on Pre-treatment measurements of experimental blocks. Northern Arizona University unpublished manuscript.

Harrington M.G. and S.S. Sackett. 1992. Past and present fire influences on southwestern ponderosa pine old growth. *In* Old-growth forests in the Southwest and Rocky Mountain regions: proceedings of a workshop, p. 81-99. USDA For. Serv. Gen. Tech. Rep. RM-213. 201p.

White, A.S. 1985. Presettlement regeneration patterns in a southwestern ponderosa pine stand. Ecology 66:589-94.

Woolsey, T.S. Jr. 1911. Western yellow pine in Arizona and New Mexico. USDA For. Serv. Bull. 101. 64pp.

Plot Protocols for PIPO

GENERAL PROTOCOLS		YES (√)	NO (√)		YES (√)	NO (√)
Preburn	Control Plots/Opt		√	Herb Height/Rec	√	
	Herbaceous Density/Opt		√	Abbreviated Tags	√	
	OP/Origin Buried		√	Crown Intercept/Opt		√
	Voucher Specimens/Rec	√		Herb. Fuel Load/Opt		√
	Stereo Photography/Opt		√	Brush Individuals/Rec	√	
	Belt Transect Width	2 x 50 meters		Stakes Installed: All		
	Number of Belts recorded	2				
	Herbaceous Data and Brush Data Collected at: Q4-Q1 and Q3-Q2					
Burn and Postburn	Duff Moisture/Rec		√	Flame Zone Depth/Rec	√	
	Herbaceous Data/ Opt		√	Herb. Fuel Load/Opt		√
	100 Pt. Burn Severity/Opt	√				

FOREST PLOT PROTOCOLS		YES (√)	NO (√)		YES (√)	NO (√)
Overstory	Area sampled	50 x 20 m		Quarters Sampled	Q1,Q2,Q3,Q4	
Note: DRC for multiple-stemmed JUOS >2 stems/tree.	Tree Damage/Rec	√		Crown Position/Rec	√	
	Dead Tree Damage/Opt		√	Dead Crown Position/Opt	√	
Pole-size	Area Sampled	25 X 20 m		Quarters Sampled	Q1 & Q2	
	Height/Rec	√		Poles Tagged/Rec	√	
Seedling	Area Sampled	25 X 10 m		Quarters Sampled	Q1	
	Height/Rec	√		Seedlings Mapped/Opt		√
Fuel Load	Sampling Plane Length	100 feet		Fuel Continuity/Opt		√
	Aerial Fuel Load/Opt		√			
Postburn	Char Height/Rec	√		Mortality/Rec	√	

FMH-4 MONITORING TYPE DESCRIPTION SHEET
Grand Canyon National Park

Monitoring Type Code: FPIPN1D09

Monitoring Type Name: North Rim Ponderosa Pine (PIPN)

Prepared by: Tonja Opperman and Ken Kerr

Date: December 18, 1999

PHYSICAL DESCRIPTION
Located at 6,900 to 8,900 feet elevation on the North Rim with slopes from 0% to 60%, including all aspects and depending on elevation. Soils are moderately shallow on ridgetops with silty loams occurring in drainage bottoms. All soils are derived from Kaibab limestone parent material.

BIOLOGICAL DESCRIPTION
Total canopy cover is at least 25%. *Pinus ponderosa* dominates the overstory[2], comprising at least 80% of overstory species. Other possible overstory species include occasional *Abies concolor*, *Populus tremuloides*, *Pseudotsuga menziesii*, and *Picea engelmanni*. The understory is composed of mostly (75% or more) *Pinus ponderosa* poles. Common brush species are *Robinia neomexicana*, *Berberis repens, Rosa fendleri*, and *Ceanothus fendleri*. Common herbaceous plants include *Achillia lanulosa, Carex* spp., *Poa fendleriana, Sitanion hystrix,* and *Viguiera multiflora.*

REJECTION CRITERIA
Large rock outcroppings or barren areas >20% of the plot; areas with anomalous vegetation, boundary fences; areas within 30 meters of roads, utility corridors, human-created trails, human-created clearings, or slash piles; areas within 10 meters of significant historic or prehistoric sites or transitional ecotones; areas burned in the last 10 years; areas with >20% overstory cover of trees other than ponderosa pine; areas with pole densities including >25% species other than ponderosa pine, and areas with >50% canopy cover of Robinia neomexicana.

DESIRED FUTURE CONDITION
At this time a literature search has been initiated to determine the desired future condition of North Rim *Pinus ponderosa* at Grand Canyon National Park, but it is not complete. These forests were likely open stands with relatively few, large overstory trees, dominated by an herbaceous understory. Research suggests in one study that there were 56 *Pinus ponderosa* trees per acre (138 trees/ha) in North Rim *Pinus ponderosa* stands (Covington 1992), and in another study that there were 40-55 trees/acre (99-136 trees/ha) on the Kaibab Plateau during presettlement times. Pole-sized trees less than six inches in diameter (15 cm) were estimated to be in groups of 200-400 but no density figures are given (Rasmussen 1941). The fire frequency on the North Rim is estimated at 2 to 15 years for these elevations (Wolf and Mast 1998), but this study did not incorporate forests on the very southernmost parts of the plateaus. It is likely that the forests on the edges of the North Rim plateaus were less dense due to drier conditions and more frequent lightning-caused fires. Fuel loads ranged from 0.2 to 9.3 tons/acre (0.5-23 tons/ha) (Covington 1992). An increase in postburn fuel loads is acceptable after the initial prescribed fire treatments.

BURN PRESCRIPTION
Units will be burned during the growing, dormant, and transition seasons from summer (June) to fall (November). In drier years the time period may move into April and/or December. The following values present a range of conditions that may be used to accomplish objectives. Optimal values and relationships exist between these ranges that relate to on-the-ground fire effects achieved as well as resistance to control. Prescription element ranges and objectives were developed using past experience, BEHAVE program, and FOFEM program.

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[2] Overstory trees are defined in the Fire Monitoring program as trees with a diameter at breast height of 15 cm (6 in) or greater. This definition does not take individual tree dominance or crown position into account.

Fire Prescription Elements	
RH = 10-80%	Live Fuel Moisture = n/a
Dry Bulb = 40-80 F	Average Flame Length = 1-10 feet
Average Mid-flame Winds=0-15mph G30mph	Average Rate of Spread = 1-40 chs/hour
10-hour TLFM = 3-15%	1000-hour TLFM = 9-25%

MONITORING VARIABLES IN ORDER OF IMPORTANCE
1. Overstory density
2. Fuel Load
3. Pole density

PRESCRIBED FIRE PROJECT OBJECTIVES—First Entry Burn
Immediately Post-Burn:
1. Reduce total fuel load by at least 30% on average, as measured over the landscape immediately post-burn (fuel reduction efforts will continue until the Desired Future Condition of 0.2-9.3 tons/acre is achieved).
2. Limit crown scorch to 30% on *Pinus ponderosa* with dbh greater than or equal to 16" (40 cm).

Two Years Post-Burn:
1. Reduce Pinus ponderosa poles with dbh of 1-6 inches (2.5-15 cm) to average 0-200 trees/acre (0-494 trees/ha). *This is a conservative target and more research is needed to define a better pole density target; Preburn pole densities range from 0-500* Pinus ponderosa *trees/acre (1235 trees/ha) and average of 51 trees/acre (126 trees/ha) in this monitoring type on 6 plots*.

Five Years Post-Burn
1. Achieve and maintain a five-year post-burn density of 19-25 trees/acre of *Pinus ponderosa* in the 16"+ size class.

PRESCRIBED FIRE PROJECT OBJECTIVES—Second Entry Burn
Objectives will be written for this section, once results from first entry burn are known.

PRESCRIBED FIRE PROJECT OBJECTIVES—Third Entry Burn
Objectives will be written for this section, once results from first and second entry burns are known.

FIRE MONITORING OBJECTIVES
1. Install enough plots to be 80% confident that overstory ponderosa pine density figures are within 20% of the true population mean.
2. Install enough plots to be 80% confident that total fuel load estimates are within 20% of the true population mean.
3. Install enough plots to be 80% confident that pole density estimates are within 20% of the true population mean.

DATA ANALYSIS
See FMH-4 Data Analysis Checklist

Literature Cited

Covington, W.W. and M.M. Moore. 1992. Postsettlement changes in natural fire regimes: implications for restoration of old-growth ponderosa pine forest. *In* Old-growth forests in the Southwest and Rocky Mountain regions: proceedings of a workshop, p. 81-99. USDA For. Serv. Gen. Tech. Rep. RM-213. 201p.

Rasmussen, D.I. 1941. Biotic communities of Kaibab Plateau, Arizona. Ecol. Monogr. 11:229-76.

Wolf, J. and J. Mast. 1998. Fire history of mixed-conifer forests on the North Rim, Grand Canyon National Park, Arizona. Physical Geography, 19, 1, pp. 1-14.

Plot Protocols for PIPN

GENERAL PROTOCOLS		**YES (√)**	**NO (√)**		**YES (√)**	**NO (√)**
Preburn	Control Plots/Opt		√	Herb Height/Rec	√	
	Herbaceous Density/Opt		√	Abbreviated Tags	√	
	OP/Origin Buried		√	Crown Intercept/Opt		√
	Voucher Specimens/Rec	√		Herb. Fuel Load/Opt		√
	Stereo Photography/Opt		√	Brush Individuals/Rec	√	
	Belt Transect Width	2 x 50 meters		Stakes Installed: All		
	Number of Belts recorded	2				
	Herbaceous Data and Brush Data Collected at: Q4-Q1 and Q3-Q2					
Burn and Postburn	Duff Moisture/Rec		√	Flame Zone Depth/Rec	√	
	Herbaceous Data/ Opt		√	Herb. Fuel Load/Opt		√
	100 Pt. Burn Severity/Opt	√				

FOREST PLOT PROTOCOLS		**YES (√)**	**NO (√)**		**YES (√)**	**NO (√)**
Overstory	Area sampled	50 x 20 m		Quarters Sampled	Q1,Q2,Q3,Q4	
	Tree Damage/Rec	√		Crown Position/Rec	√	
	Dead Tree Damage/Opt		√	Dead Crown Position/Opt	√	
Pole-size	Area Sampled	25 X 20 m		Quarters Sampled	Q1 & Q2	
	Height/Rec	√		Poles Tagged/Rec	√	
Seedling	Area Sampled	25 X 10 m		Quarters Sampled	Q1	
	Height/Rec	√		Seedlings Mapped/Opt		√
Fuel Load	Sampling Plane Length	50 feet		Fuel Continuity/Opt		√
	Aerial Fuel Load/Opt		√			
Postburn	Char Height/Rec	√		Mortality/Rec	√	

Rec = Recommended   Opt = Optional

FMH-4 MONITORING TYPE DESCRIPTION SHEET
Grand Canyon National Park

Monitoring Type Code: FPIAB1D09

Monitoring Type Name: Ponderosa Pine with White Fir Encroachment (PIAB)

Prepared by: Tonja Opperman and Ken Kerr

Date: December 18, 1999

PHYSICAL DESCRIPTION
Located at 8000 to 9000 feet elevation on the North Rim with slopes from 0% to 60%, including all aspects. Soils are moderately shallow on ridgetops with silty loams occurring in drainage bottoms. All soils are derived from Kaibab limestone parent material.

BIOLOGICAL DESCRIPTION
Total canopy cover is at least 25% but can near 100%. It is a mixed conifer forest dominated by *Pinus ponderosa, Abies concolor*, and *Populus tremuloides* with the greatest basal area in *Pinus ponderosa* even though there may be more overstory[3] *Abies concolor* stems per acre. Other possible overstory species include *Pseudotsuga menziesii*, *Picea pungens*, *Abies lasiocarpa,* and *Picea engelmanni*. The understory is composed of mostly *Abies concolor* (25 to 100%), *Pinus ponderosa, Populus tremuloides*, and *Pseudotsuga menziesii*. Common brush species are *Amelanchier utahensis*, *Berberis repens,* and *Robinia neomexicana.* Common herbaceous plants include *Bouteloua gracilis*, *Carex* spp., *Fragaria ovalis, Lotus utahensis, Pedicularis centranthera,* and *Poa fendleriana.*

REJECTION CRITERIA
Large rock outcroppings or barren areas >20% of the plot; areas with anomalous vegetation, boundary fences; areas within 30 meters of roads, utility corridors, human-created trails, human-created clearings, or slash piles; areas within 10 meters of significant historic or prehistoric sites or transitional ecotones; areas burned in the last 10 years; areas where majority of basal area is not in ponderosa pine; areas with pole densities that do not include white fir as a major component.

DESIRED FUTURE CONDITION
At this time a literature search has been initiated to determine the desired future condition of North Rim *Pinus ponderosa* forests at Grand Canyon National Park, but it is not complete. Forests in the PIAB monitoring type are at a slightly higher elevation and experience slightly wetter conditions and cooler temperatures than the North Rim Ponderosa Pine (PIPN) monitoring type. *Pinus ponderosa* likely dominated these stands but occasionally other mixed conifer species were present as well as pockets of *Populus tremuloides*. At the 8200' elevation on the North Rim, research suggests the stands were comprised of 51 overstory *Pinus ponderosa* per acre (126 trees/ha) with a mixture of *Abies concolor* and *Populus tremuloides* equally occupying the remaining 40 overstory trees per acre (99 trees/ha) (Covington et. al. 1998). Fire likely occurred in these stands every 4-15 years (Wolf and Mast 1998). Pre-European settlement fuel load estimates are unknown, but are likely greater than the PIPN forest type to the south. A conservative estimate for desired average fuel load is 0.2 to 20 tons/acre, but this figure should be revised as new information is available. Pole density figures for this forest type are also unknown, but again, are likely to be more dense than the drier forests to the south.

BURN PRESCRIPTION
Units will be burned during the growing and dormant seasons from summer (June) to fall (November). In drier years the time period may move into April and/or December. The following values present a range of conditions that may be used to accomplish objectives. Optimal values and relationships exist between these ranges that relate to on-the-ground fire effects achieved as well as resistance to control. Prescription element ranges and objectives were developed using past experience, BEHAVE program, and FOFEM program.

[3] Overstory trees are defined in the Fire Monitoring program as trees with a diameter at breast height of 15 cm (6 in) or greater. This definition does not take individual tree dominance or crown position into account.

Fire Prescription Elements	
RH = 10-80%	Live Woody Fuel Moisture = 60-250%
Dry Bulb = 40-80 F	Average Flame Length = 0.5 – 30 feet
Mid-flame Winds=0-15mph G30mph	Average Rate of Spread = 1-40 chs/hour
10-hour TLFM = 3-15%	1000-hour TLFM = 9-25%

MONITORING VARIABLES IN ORDER OF IMPORTANCE
1. Overstory density
2. Fuel Load
3. Pole density

PRESCRIBED FIRE PROJECT OBJECTIVES—First Entry Burn
Immediately Post-Burn:
1. Reduce total fuel load by at least 30% on average, as measured across the landscape immediately post-burn (fuel reduction efforts will continue until the Desired Future condition of 0.2 to 20 tons/acre (average) is achieved).
2. Limit crown scorch to 30% on *Pinus ponderosa* with dbh greater than or equal to 16" (40 cm).

Two Years Post-Burn:
1. Reduce *Abies concolor* poles in 1-6" (2.5-15 cm) size class by 20-70% to average less than 100 trees/ac (247 trees/ha). *This is a conservative target until more research indicates a better target. Preburn* Abies concolor *pole densities average 237 trees/ac, and* Pinus ponderosa *poles average 31 trees/ac (77 trees/ha) in this monitoring type on 21 plots*.

Five Years Post-Burn
1. Achieve and maintain a five-year post-burn density of 19-25 trees/acre of *Pinus ponderosa* in the 16"+ size class.

PRESCRIBED FIRE PROJECT OBJECTIVES—Second Entry Burn
Objectives will be written for this section, once results from first entry burn are known.

PRESCRIBED FIRE PROJECT OBJECTIVES—Third Entry Burn
Objectives will be written for this section, once results from first and second entry burns are known.

FIRE MONITORING OBJECTIVES
1. Install enough plots to be 80% confident that overstory ponderosa pine density figures are within 20% of the true population mean.
2. Install enough plots to be 80% confident that total fuel load estimates are within 20% of the true population mean.
3. Install enough plots to be 80% confident that white fir pole density estimates are within 25% of the true population mean.

DATA ANALYSIS
See FMH-4 Data Analysis Checklist

Literature Cited

Covington, W.W., M.M. Moore, P.Z. Fule, H.B. Smith. 1998. Grand Canyon Forest Ecosystem Restoration Report on Pre-treatment measurements of experimental blocks. Northern Arizona University unpublished manuscript.

Wolf, J. and J. Mast. 1998. Fire history of mixed-conifer forests on the North Rim, Grand Canyon National Park, Arizona. Physical Geography, 19, 1, pp. 1-14.

Plot Protocols for PIAB

GENERAL PROTOCOLS		**YES (√)**	**NO (√)**		**YES (√)**	**NO (√)**
Preburn	Control Plots/Opt		√	Herb Height/Rec	√	
	Herbaceous Density/Opt		√	Abbreviated Tags	√	
	OP/Origin Buried		√	Crown Intercept/Opt		√
	Voucher Specimens/Rec	√		Herb. Fuel Load/Opt		√
	Stereo Photography/Opt		√	Brush Individuals/Rec	√	
	Belt Transect Width	2 x 50 meters		Stakes Installed: All		
	Number of Belts recorded	2				
	Herbaceous Data and Brush Data Collected at: Q4-Q1 and Q3-Q2					
Burn and Postburn	Duff Moisture/Rec		√	Flame Zone Depth/Rec	√	
	Herbaceous Data/ Opt		√	Herb. Fuel Load/Opt		√
	100 Pt. Burn Severity/Opt	√				

FOREST PLOT PROTOCOLS		**YES (√)**	**NO (√)**		**YES (√)**	**NO (√)**
Overstory	Area sampled	50 x 20 m		Quarters Sampled	Q1,Q2,Q3,Q4	
	Tree Damage/Rec	√		Crown Position/Rec	√	
	Dead Tree Damage/Opt		√	Dead Crown Position/Opt	√	
Pole-size	Area Sampled	25 X 20 m		Quarters Sampled	Q1 & Q2	
	Height/Rec	√		Poles Tagged/Rec	√	
Seedling	Area Sampled	5 X 10 m		Quarters Sampled	Q1	
	Height/Rec	√		Seedlings Mapped/Opt		√
Fuel Load	Sampling Plane Length	50 feet		Fuel Continuity/Opt		√
	Aerial Fuel Load/Opt		√			
Postburn	Char Height/Rec	√		Mortality/Rec	√	

Rec = Recommended Opt = Optional

APPENDIX B

GRCA Categorical Exclusion Form

CE#__GRCA-01-0003_____ (Compliance Office) **Date**: August 22, 2000

Project Title: Research and Research Permitting

Project Location: Grand Canyon National Park and Glen Canyon National Recreation Area

Originating Company or Division: Science Center Research Program

Project Initiator/Manager: Robert Winfree/Della Snyder

Desired Starting Date: 8/11/00

Describe the project briefly. *(If applicable, reference the attached project proposal, Environmental Screening Form, maps, reports or sketches.):*

Approximately 85 research permits and 100 research access permits are processed annually. About half of the research in Grand Canyon is carried out as a requirement of the Grand Canyon Protection Act. Many other studies are closely tied to other regulatory (endangered species and cultural resource protection), or legislative (Forest Ecosystem Restoration Research) mandates. New projects are described in study plans and applications submitted by the principal investigators. Government or private research, educational or resource management organizations employ most investigators. Study plans are distributed to Grand Canyon, Flagstaff, and Page (GLCA) for a two-week (minimum) review and comment period. Other interested parties are notified of new proposals by E-mail.

Permitted activities occur throughout Grand Canyon National Park (GRCA) and in the Colorado River corridor of Glen Canyon National Recreational Area (GLCA). A letter of agreement between the park superintendents covers GRCA permitting of GLCA activities.

This is an ongoing program and is required under federal law and policy. Individual studies are permitted for up to five years, in accordance with NPS national policy, but most projects are completed within two years. Scope varies by project, some studies being sharply focused, and some projects surveying the full length or area of the park. Most projects occur at ground or water level, although some involve aircraft, satellite imaging, or even take place below ground (e.g. caving) or water level (sediment sampling).

Also, please see **Project Scoping Document** for more information.

Is proposal consistent with approved park plans? Yes__X_ No____ (*If no, provide reason for non-compliance):*

Describe impacts to affected resources: *(i.e. soils, vegetation, historic structure, archaeological site, cultural landscape, threatened/endangered species or habitat, visual, etc):*

Most studies involve limited collection of natural resources (air, water, sand, rocks, vegetation, fish, etc.) as authorized under 36 CFR 2.5. Work with archaeological materials or endangered species is limited to activities already authorized under a Federal Archaeology Permit or Endangered Species Permit or under other specific federal agency authorizations. Federally funded visitor surveys are limited to those authorized by OMB.

Describe mitigation measures required to reduce significance of impact *(if required):*

Alternatives are considered for any activities proposed to occur in areas managed as Wilderness, or whenever there is potential for resource impacts or visitor disturbance. Alternatives are documented in study plans, project administrative records, or according to the approved Minimum Requirement Process. Proposed projects are also screened according to other federal regulations to determine whether they are appropriate within a National Park area. Permanent administrative records are maintained in the park's research office for all research and collecting permits.

Mitigation is considered during planning for any activities recognized to have potential resource impacts. Mitigation activities are described separately in study plans, work plans, minimum requirement analyses, permit stipulations, or other documents as appropriate. Common mitigation measures involve use of less intrusive equipment, timing activities when visitors are not present, and site clean-up or restoration.

Cite the categorical exclusion used to exclude the action from further NEPA analysis *(see 516 DM Chapter 2, appendix 1, the categorical exclusion section in the SOP or Section 3-4 of NPS-12 (DO-12)):*

516 DM 2, Appendix 1, CX 1.6

Do any exceptions apply? Yes ___No X____ *(If yes, briefly explain):*

"On the basis of the environmental impact information in the statutory compliance file, with which I am familiar, I am categorically excluding the described project from further NEPA analysis. No exceptional circumstances (all boxes in the EFS are marked "NO") or conditions in section 3-6 apply, and the action is described in section 3-4 of NPS-12 (DO-12)."

____s/ Sara White____ ____10/23/00________

GRCA Chief Compliance Officer Date:

___s/ James T. Reynolds_________________________________ _____10/24/00________
Deputy Superintendent Date

APPENDIX C

REVISED

Work Plan for Grand Canyon Forest Ecosystem Restoration

Prepared by:

W. Wallace Covington
Margaret M. Moore
Peter Z. Fulé
H.B. "Doc" Smith
and
Thomas A. Heinlein

School of Forestry, Northern Arizona University, Flagstaff, AZ

October 23, 2000

NORTHERN ARIZONA UNIVERSITY

Contents

Changes in the revised work plan

This document is a revision of the draft work plan for Grand Canyon forest restoration, dated February 27, 1998. In July, 2000, Dr. Robert Winfree, Grand Canyon Senior Scientist, requested that the NAU research team prepare this revision in response to comments on the environmental assessment based on the previous work plan.

This revised work plan takes a substantially different approach to forest ecosystem restoration at Grand Canyon by proposing a slower treatment method: an "intermediate restoration" alternative instead of the original "full restoration." The advantage of this approach is that it effectively deals with concerns related to tree thinning in parks, eliminates ecological and aesthetic damage associated with mechanized equipment, and provides a longer time period to assess initial results. The disadvantage of this approach is that the restoration process becomes slower and more expensive, the end result of restoration activities is less certain, and the technical difficulty of carrying out prescribed burning may increase.

Below are summarized the changes from the previous version of the work plan:

1. No trees over 5" in diameter will be cut on the experimental sites.
2. Two years after burning, the effectiveness of the 5" limit and other aspects of the treatments will be assessed.
3. No wood will be utilized for any purpose or removed from the experimental sites.
4. Fire will be used to thin trees to the maximum extent possible.
5. No mechanized equipment will be used for thinning on the North Rim site, proposed for wilderness status.
6. No road improvements are needed. No skid trails or landings are needed.
7. Tree marking will be needed only on a demonstration basis.
8. The example burning prescription was removed. Prescriptions will be prepared by Grand Canyon staff.
9. Old trees will not have fuel raked away from the lower bole in the burn-only treatment, in order for this treatment to serve as a better analogue of current management practice.

A new section with an assessment of the implications of altering the restoration methodology is presented at the end of the text.

Introduction

Description of project

The Grand Canyon forest ecosystem restoration project will facilitate restoration of natural forest ecosystem structures and functions. A complete description of the project is presented in the research proposal "Grand Canyon Forest Ecosystem Restoration," revised June 12, 1997. The executive summary of the project is presented below. All text in italics is taken from the research proposal.

Proposal summary. *Forest ecosystems in the Grand Canyon region have undergone striking and deleterious changes as a result of elimination of the natural disturbance regime of frequent, low-intensity fires. We propose to initiate research to support ecosystem restoration of ponderosa pine and mixed conifer forests in Grand Canyon National Park. Ecological restoration provides a means to reestablish the structure, function, and integrity of indigenous ecosystems, based upon thorough understanding of the reference natural conditions. Accordingly, the first objective is to determine the range of natural variability in the reference period, prior to the modern fire-exclusion era which began with Euro-American settlement. Landscape-scale study areas (800-1,200 ha) will be established in each of the North and South Rim forests to measure contemporary ecosystem structure (trees, shrubs, forbs, grasses, and dead biomass) and to collect dendrochronological (tree-ring) and other ecological data used to reconstruct past forest structure and fire occurrence. These data will provide a quantitative basis for assessing the changes in fire-excluded Grand Canyon forests and will serve as points of* *reference for designing restoration treatments. The second objective is to test four alternative restoration prescriptions on three small-scale (32 ha [80-acre]) experimental restoration blocks. Designed as adaptive ecosystem management experiments, in which researchers and land managers work collaboratively, integrated restoration treatments will be tested at each experimental block. Testing of forest ecosystem restoration prescriptions will involve the establishment of long-term monitoring plots, development of site-specific treatment prescriptions, protection of old-growth trees, thinning of unnaturally dense stands of young trees, treatment of accumulated forest floor fuels, reintroduction of fire, and reestablishment of conditions favorable to the growth of native herbaceous plants and shrubs. This research will help provide scientists, managers, and the public with tested practices and procedures for restoring ecosystem health.*

Scope of work plan

The present document is a work plan detailing the activities required to meet objective two: testing of ecological restoration prescriptions. It describes an experiment comparing four alternative treatments on 80-acre experimental blocks located on both Rims of Grand Canyon National Park and the adjacent Kaibab National Forest. Permanent plots were established and ecological attributes were measured on each block in 1997. The alternative treatments are:

1. An intermediate ecological restoration treatment, designed to emulate the forest structure prior to disruption of the frequent-fire regime, treat fuels, and restore fire in prescription.
2. A minimal thinning treatment, designed to reduce the hazard of wildfire and facilitate the re-introduction of prescribed fire.
3. A burn-only treatment, re-introducing prescribed fire.
4. A control treatment, where fire exclusion will be maintained.

The work plan will be used to guide the planning, assessment of environmental impacts, and implementation of the restoration experiment. This work plan has been developed collaboratively with staff from NAU, Grand Canyon National Park, Kaibab National Forest, and other interested people.

Experimental design

Research hypotheses

The research hypothesis is that forests in which the keystone variables of forest structure and fire disturbance regime have been restored to conditions emulating those of presettlement forests will remain healthy, sustainable ecosystems. Relevant characteristics of ecosystem health described by Kolb et al. (1994) include resistance to catastrophic change (e.g., crownfire, high mortality from insect or disease pathogens), functional equilibrium of supply and demand for essential resources (e.g., rates of nutrient cycling, moisture relations), and diversity in seral stages and habitats (e.g., mix of tree ages, herbaceous productivity). Some of these attributes can be contrasted in the control and alternative treatments immediately following treatment: fuel reduction, tree densities, species composition, canopy cover. Others will require longer periods: herbaceous production, tree regeneration, fuel accumulation, fire mortality, changes in species diversity. The restored units are hypothesized to remain within the range of natural variability for these attributes over time, given maintenance of the prescribed burning regime. The control units are expected to remain outside the range of natural variability and remain highly vulnerable to catastrophic change.

We hypothesize that alternate treatments of burning only and minimal thinning will remain in intermediate states relative to the control and restored units. The burning treatment should reduce fuels, thin a few small-diameter trees, and lead to slight improvement in herbaceous cover. However, retention of the dense overstory will prevent a major recovery of the understory (for example, see the discussion in Sackett et al. 1996). The minimal thinning should go further toward fuel reduction, lowering the crownfire hazard, and reducing tree *density, leading to better understory production and diversity. Depending on the site, the minimal thinning may more closely resemble either the full restoration or the burn only treatments. At the relatively open Grandview sites, minimal thinning may remove only a few trees. At the Northwest site, where dense conifer thickets have developed following fire exclusion, minimal thinning may require substantial cutting.*

As discussed in the final section of this document, the adoption of modified thinning methods including a 5” diameter limit will affect the way in which the treated units will respond. Especially at the South Rim, the modified intermediate restoration treatment appears unlikely to restore conditions emulating those of pre-disruption forests. However, the effects of the modified treatments will be assessed and managers can choose to take further action in the future.

Experimental treatments

In the present proposal, three ecological restoration treatment blocks of 32 ha (80 acres) in size will be developed in cooperation with agency staff to test the restoration prescriptions, develop agency and researcher expertise, and provide interpretive examples to the public and other land management organizations. These experimental blocks could serve as the nuclei for larger-scale restoration treatments carried out by agency staff in the future. In each experimental block, treatments will be randomly assigned to each of four 8 ha (20 acre) experimental units. Each unit will be measured pretreatment with permanent plots for posttreatment and future comparison. The selection of treatments has been made through a collaborative process with Park Service and outside reviewers to obtain the most useful information for managers. The treatments are (1) burning only, (2) minimal thinning to reduce fire hazard, followed by burning, (3) thinning to emulate presettlement forest structure, followed by burning, and (4) control.

A hypothetical comparison of the initial effects of these treatments on forest overstory structure is illustrated in Figure 1. Treatments are described in the Grand Canyon Forest Ecosystem Restoration proposal and in Appendices A and B of this work plan.

Analysis

The original experiment was designed as a randomized complete block. Blocking was chosen because the experimental areas cross two management agencies (Park Service and Forest Service) and two forest types: ponderosa pine/Gambel oak on the South Rim and ponderosa pine/mixed conifer on the North Rim. Prior to disruption of the frequent fire regime, the North Rim site was dominated by ponderosa pine and was structurally more similar to the South Rim site than it is today. With the modifications to the work plan, the Park experimental blocks will be treated differently than the Forest block. There was no diameter limit on thinning in the Forest block and commercially useable tree material was removed with mechanized equipment. However, the blocking design will still permit treatment-control comparisons within blocks. Furthermore, as discussed above, the intermediate restoration and minimal thinning treatments in the Park should still have reasonably similar structural effects to those originally forecast even under the modified work plan.

Following treatment, all measured variables will be compared with pre-treatment values and controls. Confidence intervals at the 90% and 95% level will be calculated and presented, rather than carrying out tests of statistical significance. Post-treatment variables will be assessed relative to their range of natural variability (RNV), as far as the RNV can be quantified. The RNV for tree structure, for example, can be quantified with a greater degree of precision than that for understory vegetation.

Experimental blocks

Location

Locations of the experimental blocks are mapped in Figures 1 and 2. The rationale for selecting the study sites and complete site descriptions are presented in detail in the proposal.

Management concerns:

Cultural

All experimental blocks were cleared by Grand Canyon National Park or Kaibab National Forest cultural resources staff. Archeological inventory surveys have been conducted at the 100% level for the experimental blocks within Grand Canyon National Park. One archeological site was located within the 80-acre experimental block on the South Rim (Grandview). Potential impacts to this site were mitigated. If additional archeological sites are located, appropriate mitigation measures will be designed and implemented prior to project implementation. Complete archeological compliance documentation was prepared and submitted to the appropriate agencies for review and concurrence as necessary.

Wildlife and special species

All experimental blocks were cleared by agency wildlife staff for general suitability of the locations. The North Rim experimental block was surveyed several times in 1997 for presence of the northern goshawk. Goshawk nests were not found in the vicinity. The block was surveyed again in 1998 (R.V. Ward, Grand Canyon Wildlife Biologist, personal communication 1999). Potential effects of the restoration experiment on listed threatened or endangered species, such as the Mexican spotted owl, were considered by agency biologists during the environmental assessment process.

The Park experimental blocks have been surveyed for the presence of special status plants. No Federally Listed Endangered or Threatened plants, nor plant species of special concern (formerly known as Category 2 plants) have been found on either block.

All dead standing presettlement trees (snags) and other trees identified by agency personnel as being important for wildlife habitat will be marked and protected during the treatments.

Wilderness

Wilderness values are a central concern in management of Grand Canyon ecosystems. Backcountry lands in Grand Canyon National Park are managed for wilderness characteristics following guidelines comparable to those for designated wilderness areas. The overarching goal of the ecological restoration project is completely complementary with these values, seeking to restore sustainable natural ecosystem processes in forest ecosystems that are currently far removed from their natural state. However, many short-term practices associated with restoration treatments present temporary conflicts with wilderness values. These practices include thinning of trees, forest floor fuel manipulation, and operation of machines. Researchers and agency staff have consulted and continue to work with wilderness coordinators to seek ways of making short-term restoration practices as compatible as possible with wilderness values, while maximizing the utility of ecological restoration as a tool for achieving desirable long-term wilderness conditions. (See Noss [1991] for discussion of wilderness restoration).

Testing of experimental low-impact technologies may be carried out by agency personnel in association with these experiments. Such treatments may include alternative means for tree, stump, and duff removal. If alternative treatments are tested, they will be carried out in portions of the experimental blocks at least 100 ft away from the ecological monitoring plots.

Soil and water resources

Effects of treatment activities on soil and surface water resources are of concern to management. Ground cover density, a measure of soil protection which is an input to soil loss modeling, will be monitored on the permanent plots before and after treatments. The South Rim blocks are nearly flat to very gently sloping with moderate existing understory plant cover. The North Rim block contains mostly gentle slopes but includes steeper slopes in the minimal thinning treatment unit. Thinned tree slash will be dispersed in all thinned units with attention to slowing water runoff and encouraging deposition of clay and silt, especially in the steeper portion of the North Rim unit. Agency personnel will monitor treatments and ensure that appropriate measures are taken to control soil erosion.

Pre-treatment sampling

Permanent plots were installed in each experimental block between July and November, 1997. Each experimental unit contains 20 plots on a 60-meter grid, approximately 1 plot per acre, for a total of 80 plots per experimental block or 240 plots over all three blocks. The suite of measurements and plot design are adapted from: (1) the Fire Monitoring system developed by the National Park Service (Reeberg 1995); (2) sampling methods developed for measuring presettlement and contemporary ecosystem structure in southwestern forests (Fulé et al. 1997); and dendroecological sampling techniques (Covington and Moore 1994).

Plot description. Plot centers are permanently marked with a rebar stake. Overstory trees over breast height (4.5') are measured on a 400 m^2 (11.28 m radius) circular fixed-area plot. Trees below breast height and shrubs are measured on a nested 100 m^2 (5.64 m radius) subplot. Herbaceous plants and canopy cover (vertical projection) are measured along a 50-m line transect oriented upslope with 25 m above and 25 m below the plot center. Fuels are measured on a 50' planar transect in a random direction from plot center. Photos are taken to plot center from 11.28 m N and E. All measurements taken are described in Table 1 of the Grand Canyon Forest Ecosystem Restoration proposal.

Pre-treatment data were collected from all plots in 1997. These data represent the contemporary (pre-treatment) condition of the experimental blocks. Fire-scarred samples were also collected from trees within and around the experimental blocks in 1997. By using dendrochronological techniques with the fire-scarred samples and tree increment cores, the past fire disturbance history will be determined and the presettlement forest structure will be reconstructed at the time of disruption of the natural frequent fire regime.

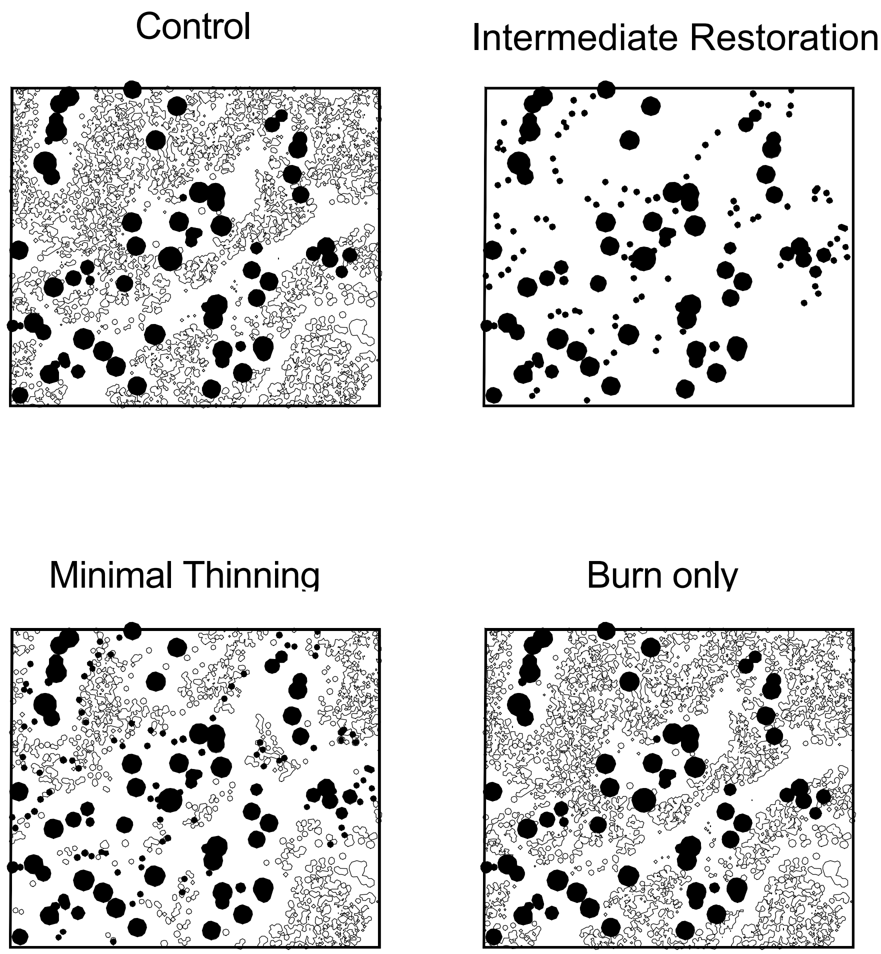

Figure 1. Comparison of thinning treatments in terms of forest overstory structure. Circles are tree crowns in a 3.7 acre (1.5 ha) portion of the Gus Pearson Natural Area near Flagstaff, AZ, stem-mapped in 1992 (Covington et al. 1997). Thinning treatments are modeled on the stem-mapped data. Filled circles are the crowns of living presettlement trees; smaller filled circles in the intermediate restoration and minimal thinning treatments are leave trees selected to replace dead presettlement trees at a ratio of 3:1, and any other trees > 5" dbh. These trees and others are retained in the minimal thinning treatment. No thinning is done in the control and burn-only treatments. Treatments are described in the Grand Canyon Forest Ecosystem Restoration proposal and in Appendices A and B.

During-treatment sampling

Fire behavior variables will be measured on the plots during the prescribed burning phase of treatment following procedures in the NPS Fire Monitoring Handbook. The variables to be measured include (1) weather: temperature, relative humidity, wind speed and direction, shading/cloud cover, and 10-hour timelag fuel moisture; (2) fire behavior: rate of spread, flame length, flame zone depth, fire direction, and fuel type; and (3) photographic record of fire behavior. These data will be used to quantify fire intensity and relate it to fire effects such as fuel consumption or plant mortality.

Post-treatment sampling

Post-treatment sampling will be carried out in the year of treatment, if possible, or the following year. Subsequent re-sampling at 3 years, 6 years, and 9 years is recommended to track changes. The research investigators intend to do this repeated sampling. In any event, however, the plot location information and data collected will be stored at Grand Canyon National Park to facilitate continuing research and monitoring.

Treatments

Activities common to all treatments

Fireline

Firelines will be prepared under the direction of agency fire management personnel. Experimental blocks were laid out to take the greatest possible advantage of existing roads and firelines. Firelines are not needed between adjacent units which will both be burned; only the control unit needs to be separated from the others.

Firelines will be established around each 80-acre experimental block and around the control treatment within each block. Control treatments are designed to remain as unburned treatments through a long-term monitoring period and site-specific prescriptions will be developed to emulate presettlement fire regime characteristics at the other treatment units. The forest surrounding the blocks will continue to be managed according to current agency management direction. Firelines are therefore necessary to prevent fire from spreading into or away from the experimental units. Agency guidelines will be followed in establishing firelines. Typical considerations in fireline preparation include: clearing organic material down to mineral soil; ensuring that flammable vegetation and downed wood is removed back from both sides of the fireline; following appropriate natural firebreaks and safe topographic positions; cutting cup trenches to catch rolling burning materials on underslung firelines; and installing waterbars. Firelines may be moved outward slightly as needed to miss presettlement trees, take advantage of existing fuelbreaks, and minimize visual impact.

Activities common to all treatments except Controls and Burn-only

Old tree protection

Heat has been documented to be a major cause of mortality of old-growth ponderosa pine trees following prescribed burning (Ryan and Frandsen 1991, Swezy and Agee 1991, Sackett et al. 1996, Covington et al. 1997). Lethal temperatures develop in deep duff layers that have accumulated over extended periods of fire exclusion. Stem charring is also associated with increased mortality (Wyant et al. 1986). Mortality of old trees from burning appears to be a minor problem at Grand Canyon and on the Kaibab Plateau, as compared with other sites in northern Arizona (Dan Oltrogge, GRCA, and Mark Baron, KNF, personal communication, 1997). However, these old trees are the slowest organismic variable in the ecosystem, so ensuring their survival through the course of the restoration treatment is a high priority. Therefore, old-tree protection is included in all treatments except the control and burn-only. Similar protection is provided for old-growth snags. At the request of fire management staff, old tree protection was removed from the burn-only units so that this treatment would better represent current management practice.

Old tree protection is achieved by removing accumulated duff from around the base of all presettlement trees. The removed material is scattered and burns rapidly with flaming--rather than glowing--combustion once it has been separated from the thick duff. Because heat intensity drops exponentially with distance from the combustion source, even a short fuelbreak (6-12") is adequate to prevent lethal cambial temperatures during burning (Steve Sackett and Sally Haase, PSW Fire Lab, personal communication, 1997).

Alternatives: duff removal can be done with (1) hand or (2) power tools.

(1) Hand tools: McLeod rakes are used to break up accumulated duff material and drag it away for a distance of 1.5' to 2.5' from the bole. Only approximately 6"-12" is necessary for adequate heat reduction (Sally Haase, USDA Forest Service Riverside Fire Lab, personal communication 1999). One- or two-person crews can treat a tree in 4-12 minutes, depending on the duff depth and on the crew condition. The removed material is piled in a ring around the tree. Because this material is fluffed and no longer tightly packed, the ring burns quickly with the flaming front and does not appear to contribute to bole char or soil heating.

(2) Power tools: heavy-duty leaf blowers are used to scatter duff. A two-person crew includes one person to break up the duff layer with a McLeod tool, while the operator follows to blow the duff out. Typically the fuelbreak is more narrow (6-12"). Both people need to wear eye and ear protection. A crew can treat a tree somewhat faster than with hand tools. Over the course of a day, the blower is less tiring than using hand tools. However, the weight, vibration, and noise do contribute to fatigue. Concerns relating to this treatment include: noise; safety from blowing objects; and tool costs.

Proposed alternative: Hand tools, alternative (1), are proposed because they are only moderately slower than the blower and do not raise noise or safety concerns.

Burning prescription

The burning prescription will be prepared by agency fire management staff. Burning of all the non-control treatments together is preferred, but the different fuel conditions corresponding to the different treatments may require adjustments in the prescription.

An initial burn would follow completion of the thinning treatments. The first burn is most likely to occur in the autumn when appropriate burning prescription windows are most available. After the first burn, the experimental blocks should be re-burned at intervals similar to the presettlement fire regime. Whenever possible, prescribed burning should emulate the seasonal and inter-annual fluctuations characteristic of the presettlement regime, such as the relationship between fire and El Niño weather patterns (Swetnam and Baisan 1996). A comprehensive analysis of the presettlement fire regimes in the regions surrounding the experimental blocks has been carried out simultaneously with the experimental treatments described here. This study can help serve as a site-specific guide to assist in matching contemporary prescribed fire patterns to presettlement patterns (Fulé et al. in press and report on file at Grand Canyon National Park).

Intermediate restoration treatment

Thinning prescription

The thinning prescription for the intermediate restoration treatment is attached (Appendix A). Researchers and agency staff will work together during a training period to ensure that the prescription is clear and that problems and questions are resolved. Follow-up reviews will be conducted by research and agency staff.

Marking

Tree marking requirements have been reduced due to the 5" diameter limit on thinned trees. Currently we recommend that only leave trees below 5" in diameter be marked. Aspen trees will not be thinned and should not be marked. Marking alternatives are evaluated below.

Leave trees are marked in the intermediate restoration treatment. Marks should be highly visible to ensure that trees are retained and to help thinning operators avoid damage to them. Trees should be marked low to the ground, in addition to a higher, more visible mark, in order to allow managers to account for any leave trees which are cut. Marks should be durable so that remarking will not be necessary in case thinning operations are delayed.

Although high visibility of marking is desirable during the thinning treatment, persistant marks are considered undesirable in a park or wilderness setting. Three *alternative marking methods* are considered: (1) marking paint; (2) flagging; and (3) a mix.

(1) Marking paint: tree marking paint is highly durable and visible. However, the marks may be visible for 10 or more years.

(2) Flagging: flagging is visible and can be removed after thinning. However, flagging can easily fall off the trees, especially if there is an extended period between marking and thinning. Because leave trees are marked, the loss of marking flags would result in excessive trees being cut, including presettlement trees. Finally, temporary marking flags cannot serve as evidence of cutting of any leave trees.

(3) Mix: paint and flagging can be used in combination. Trees would be painted at ground level, providing a durable mark and a check on cutting of leave trees. The paint would be relatively inconspicuous and would be obscured following treatment by both charring and growth of herbaceous plants and shrubs. The trees would also be marked at breast height with flagging, providing a visible--but temporary--mark. Leave trees would have to be checked for lost flags right before treatment.

Proposed alternative: the mix of paint and flagging, alternative (3), is proposed, consisting of one strip of bright florescent flagging at breast height and a 2 in bright green paint spot about 1 in above ground level only for trees other than aspen below 5" in diameter.

Tree cutting

The objectives of tree cutting are to fell trees safely, avoid damage to residual trees or other plants, leave low stumps, and be efficient. Three *alternative methods* for tree cutting include (1) hand tools; (2) power tools; and (3) mechanized equipment.

(1) Hand tools: include the crosscut saw and axe, for larger trees, and bowsaws and axes for smaller trees. The only advantage of hand tools is their compatibility with wilderness management values. There are

few experienced users of traditional tools, so operators would have to be trained. Although few contemporary examples of this type of work exist, apparently a skilled crew can fell trees safely and rapidly at a speed not much slower than that of a crew using chain saws (K. Crumbo, Grand Canyon Wilderness Coordinator, personal communication 1997). Felling direction can be controlled to minimize damage to residual plants. Disadvantages of hand tools include relatively higher stumps--both to allow clearance for the saw and to protect the operators' backs--and greater fatigue and chance for injury, as well as a substantial decline in efficiency for post-felling operations such as limbing and bucking, compared to chain saws. Time estimate: crew of 6, assume approximately 3 weeks per treated unit (20 acres/8 ha).

(2) Power tools: include chain saws and thinning saws (circular saw blades mounted below an extended handle, powered by a motor carried by the operator). Power tools are highly efficient and experienced operators and training opportunities are already part of agency operations (e.g., fire crews). Operators can safely fell trees, avoid residual plants, and leave low stumps. Limbing and bucking can be done rapidly. Disadvantages of power tools include noise and motorized operation during the treatment period. Time estimate: crew of 6, assume approximately 1 week per treated unit.

(3) Mechanized equipment: trees can be cut by feller-bunchers, tractors equipped with grasping arms and a saw or shears in the front. Feller-bunchers are rapid and usually leave low stumps. Damage to residual trees can be avoided by using the arms to control felling direction. Feller-bunchers are the safest alternative because the operator is in an enclosed protective cage during tree felling. By bunching the fallen trees, skidding travel and associated soil disturbance may be reduced. Disadvantages of feller-bunchers include noise and motorized operation, as above, as well as soil and forest floor disturbance associated with operation of the equipment. Not all trees can be handled by the feller-buncher for reasons of size or access; some trees would have to be felled with other tools. Time estimate: crew of 4, assume approximately 1 week per treated unit.

The *proposed alternative* is the use of hand tools, alternative (1), at the North Rim site because of the proposed wilderness designation of this area. Since the use of hand tools is expected to increase the time and cost of the thinning, the Park should consider a power tool alternative if acceptable contractors cannot be found within budget. The proposed alternative is the use of power tools, alternative (2), at the South Rim site.

Stumps

Height

All stumps will be cut flat and as low to the ground as possible. Stump heights should be 3 in or less, but this target may not always be met due to nearby rocks, other impediments, or safety concerns. Where hand tools are used (North Rim site), the standard should be to cut stumps as low to the ground as is feasible.

Persistence (duration of visible stump)

The presence of stumps is a persistent visual reminder of forest restoration treatments. Stumps may be perceived as unnatural by Park visitors and may appear incompatible with the visual elements of a wilderness scene. High or slanted stumps may be hazardous to people and animals moving through the forest.

Alternatives: (1) no additional treatment; (2) chemical treatment; (3) stump pulling; (4) stump grinding and (5) stump blasting. These alternatives are discussed below.

(1) No additional treatment: stumps would be left to decompose and be consumed in fire. Hazards of high or slanted stumps would be prevented by cutting low, flat stumps. The stumps which have persisted for 100+ years in fire-excluded forests are from mature trees which had developed thick heartwood before harvesting. Because the great majority of stumps would be from small, young trees without resinous heartwood, decomposition would occur quickly. Evidence of extensive thinning of small-diameter ponderosa pine trees at Taylor Woods, north of Flagstaff, has mostly disappeared within 30 years. Stumps of white fir and Gambel oak will decompose even faster than pine. With repeated fire, many stumps will be consumed after they dry out (1-2

years). The response of grasses, forbs, and shrubs to restoration treatments will also conceal stumps from view. The majority of small-diameter stumps at the Gus Pearson restoration site, north of Flagstaff, were difficult to see due to grass cover within two years of treatment. Under the no treatment alternative, there are no concerns relating to introduction of chemicals, noise, cost, safety, or soil disturbance.

(2) Chemical treatment: chemical agents would be applied to stumps to increase the rate of decay. In a comparative study, Hickman and Perry (1994) found no short-term (8 weeks) effect of 3 commercial stump removers and 3 nitrogen-containing fertilizers on stump decay. The application method was to drill several holes in the top of each stump and add the chemical agent and hot water. Hot water was re-applied after 2 hours. Wilson (1982) also expressed doubts about the efficacy of chemical treatments. Concerns relating to this treatment include: time expended, perhaps 5-15 minutes per stump; chemical costs; exposure to chemical agents by workers, Park visitors, and wildlife; addition of off-site fertilizing agents; noise of drilling; and possible minimal effectiveness.

(3) Stump pulling: a chain or jaws would be used to pull stumps from the ground. Wilson (1982) reviewed a number of stump extraction methods using tractors and chains or cables. Stumps must be left relatively high, and sometimes notched, to provide purchase for the chain. Concerns relating to this treatment include: time expended; tractor costs; soil disturbance and noise associated with tractor operation; soil disturbance from the pulled stump; erosion in the stumphole and burial of vegetation by dislodged soil; and disposal of the removed stumps.

(4) Stump grinding: a specialized grinding tool would be applied to cut or grind stumps into smaller pieces, making them less conspicuous and more susceptible to decay. Stump grinders are motor-driven tools with carbide cutting blades, either wheeled or designed for attachment to a small tractor like a Bobcat (Harler 1997). Concerns relating to this treatment include: time expended; tool costs; soil disturbance and noise associated with tool or tractor operation; and soil disturbance around the stump.

(5) Stump blasting: explosives are used to shatter and/or uproot stumps. Explosive charges are placed around the stump or within drilled holes (Mackenzie [year?], Wilson 1982). The objective may be simply to shatter the stump, creating an appearance which may be perceived as more natural, or to uproot the stump. Only certified users can set the charges. Concerns relating to this treatment include: safety of workers, Park visitors, and wildlife; high noise; ensuring that all charges are detonated; time expended and costs of explosives; soil disturbance around stumps; specialized explosive storage requirements; and chemical residue from explosives.

Proposed alternative: no additional treatment, alternative (1), is proposed, because the great majority of stumps will be small given the 5" diameter limit on thinning. They will be hidden from view rapidly by grass and will decay or burn within a few years. This alternative is the simplest and presents no concerns about safety or ecological impacts.

Root disease

Fungal root diseases such as *Armillaria* and *Heterobasidion annosus* can spread among the interconnected root systems of stumps and residual trees, causing mortality. These root diseases are infrequent in northern Arizona pine or pine-oak forests, such as experimental blocks 1 and 2, but may be of concern in the mixed conifer site at experimental block 3. White fir and Douglas-fir are preferred hosts, but infection can spread to pines. Evidence of root disease, such as mycelial ("latex") fans or clusters of dying trees, were not observed at experimental block 3 during pretreatment sampling in 1997. Thinning in late summer should limit the potential residence time for fungi, permitting stumps to dry out over the winter, reducing their quality as hosts.

Tree removal

Tree removal will not occur under the modified work plan. However, slash within the treatment units will be re-arranged to minimize heat damage to residual trees. In particular, slash will be pulled away from the boles and under the crowns of presettlement trees, insofar as feasible, as described below.

Skid trails

Skid trails are routes used to skid or drag logs from the stump to a landing or road. No skid trails will be required under the modified work plan.

Roads

The experimental blocks were intentionally located next to existing roads. No road construction or upgrading is anticipated to be necessary during this project.

The road access to the South Rim blocks is Forest Road (FR) 310, an all-weather road that connects State Highway 64 (inside Grand Canyon National Park) with FR 301 in the Kaibab National Forest. This road should be suitable for all types of trucks and equipment in all weather conditions.

Road access to the North Rim block is the Swamp Ridge road (W4), an unimproved dirt road. Approximately 1.5 miles from the North Rim experimental block, the Swamp Ridge road connects with FR 268b on the Kaibab National Forest. This road is constructed to a higher standard for all-season use and connects with other all-season roads that give access to State Highway 67 or FR 22, the West Side road that leads to US 89A at Fredonia.

The only road use will be to transport work crews, who will park vehicles safely along the road shoulders.

Landings

Landings are open areas where logs or other forest materials are aggregated and stored until they can be removed from the site. No landings will be required under the modified work plan.

Slash

Slash will be broadcast burned in the intermediate restoration and minimal thinning treatment. Slash should be lopped in 2-4' lengths to ensure more rapid drying and combustion, and to minimize infestation by *Ips* spp. bark beetles, and scattered. The distribution of slash should be consistent with the goals of protecting old trees and all residual vegetation, by avoiding old trees, fire-susceptible residual trees such as aspen, oak, and firs, and areas where existing understory plants could be damaged by the slash itself or by the fire. The slash should be burned quickly, to minimize its quality as a host for pathogens and to remove wildfire risk. Orozco and Carrillo (1992-93) reviewed prescribed burning of red (recently cut) ponderosa pine slash, noting that these fine fuels caused fire behavior similar to that of grass fuel models: relatively high flame lengths but short residence time and low heating per unit area. Scorch and mortality of residual trees was low. Although the majority of the larger woody fuels would probably not be consumed during the first burn, most of these fuels will eventually burn in subsequent fires.

Fuel loads arising from this experiment can be predicted in general (see Tables 1 and 2, below), but the actual site-specific fuel conditions will have to be carefully assessed after thinning. The parameters of the prescribed burn plan will also have to be considered. If post-thinning fuel loads are excessive in terms of safety or potential fire effects, in the professional judgment of fire staff, then slash may be hand-piled and burned under cool conditions prior to a broadcast burn.

Chipping of slash may be carried out as an alternative or complement to lopping and scattering slash, especially where the slash fuel load might be excessive. Chips may be removed off-site or used to protect and restore erodible areas. Chipping is not planned at the Grand Canyon experimental blocks under this work plan.

Understory plants

Conserving existing understory plants is crucial to successful re-establishment of natural ecosystem structure. Sites where native herbaceous plants and shrubs exist should be protected as far as possible during thinning and slash arrangement activities.

Restoration of understory vegetation through natural succession is strongly preferred in order to maintain the genetic diversity and integrity of the ecosystem. Natural regeneration can be rapid. For example, understory vegetation recovered within 2 years at the Gus Pearson restoration site (Covington et al. 1997). However, assessment of the recovery potential of each experimental block will be made on a case-by-case basis in consultation with agency staff, before and after treatment. If a consensus is reached that new propagules (seeds, seedlings, or grass plugs) are required to prevent erosion or limit the spread of exotic pioneer species, then exclusively native seed sources with the most local provenance possible will be used. The mix of plant life forms, functional groups, and species should match the best available understanding of the reference presettlement ecosystem structure. Planting techniques and schedules will be developed in consultation with local specialists. As noted in the pretreatment report (Ecological Restoration Program 1998), the native understory communities are in relatively good condition at the North Rim and South Rim sites, so we expect natural regeneration to be highly successful. The elimination of tree removal activities in the modified work plan should be beneficial toward re-establishment of the understory and minimizing the invasion of exotic species. However, the increased density of large trees to be retained at the South Rim site under the modified work plan is expected to prevent full recovery of understory vegetation, as discussed above.

Minimal thinning treatment

Thinning prescription

The thinning prescription for the minimal thinning treatment is attached (Appendix B). Researchers and agency staff will work together during a training period to ensure that the prescription is clear and that problems and questions are resolved. It is not clear whether tree marking will be necessary, given the 5" diameter limit. We suggest that research and field crews get together to mark and thin a small test area at both North and South Rim sites to determine whether marking will be useful.

Burning prescription

The minimal thinning units will be burned under the same prescription as the other units, with appropriate consideration for the presence of slash.

Burn-only treatment

The burn-only treatment is broadly intended to represent the current fire management policy at Grand Canyon National Park (GRCA Fire Management Plan 1992). The burn-only units will be burned at the same time under the same conditions as the other units, if possible, with appropriate consideration for the relatively lighter ground fuels (because of the absence of slash) but relatively greater live tree fuels (because of the absence of thinning).

Control treatment

The control treatment is a no-action treatment, which includes deliberate continued protection from wildfire or prescribed burning. The control units must be protected from effects of thinning, so control units boundaries must be clearly flagged during thinning operations and the presence and purpose of the control unit must be made clear to thinning operators. No vehicle or equipment use is permitted within the control units. The controls must also be protected from the first and subsequent prescribed burning treatments with a secure fireline and clear communication to prescribed burn planners and operators. Because the protection should be indefinite, it is proposed that a relatively permanent fireline be constructed around the control units.

Maps of the control unit locations should be provided to fire managers and other resource managers within each agency so that their protection can be considered in future wildfire, prescribed fire, and other management activities.

Safety

Safety of workers and visitors is paramount. On the part of research crews, safety considerations include: (1) multiple vehicles and radio or telephone communication in the field; (2) first aid training (Red Cross, CPR, up to EMT) and first aid supplies; (3) fire training (S-130/190); (4) training for chain saw operators (S-212 Power saws); and (5) field training in thinning methods and fire-scarred sample collection practices. Research crew representatives will coordinate with agency safety officers to comply with agency practices and approved safety plans. Agencies will ensure that their crews and contractors comply with all appropriate safety requirements.

Educational materials will be developed by agency and NAU personnel and used to alert visitors about treatment activities. Materials may include entrance station and backcountry office brochures, signs, press releases, and on-site greeters as deemed appropriate by the agency.

Tentative schedule

Timing of treatment activities

Timing of all treatment activities will be coordinated with the appropriate agency staff. Factors relating to timing include: (1) completion of environmental documentation and official approval of treatment activities; (2) completion of any clearances required for cultural resources, wildlife, etc.; (3) consideration by agency biologists of any seasonal impact on wildlife; (4) consideration by agency managers of any seasonal impacts on visitors or public land users; (5) scheduling changes necessitated by selection of alternatives such as fall/winter operations. After a decision is made by the Park Service, demonstration, site visits, and thinning can occur in the next field season (summer) with burning most likely in the fall.

Implications of altering restoration methodology

The original research proposal and work plan included a full restoration treatment that was designed to rapidly return forest structure to conditions that emulated those prior to fire regime disruption. The structural restoration was to be initiated by thinning trees in a single entry. The underlying logic was that a fast restoration approach would be most beneficial in protecting the forest from catastrophic fire and restoring natural habitats for plants and animals. Furthermore, a single entry treatment would have limited any negative effects of treatments to one brief period.

In the range of alternative experimental treatments developed in collaboration with the Park Service, we also included a minimal thinning treatment. The minimal thinning was intended to reduce fire hazards by restoring some attributes of pre-disruption forest structure and function, although to a lesser degree than the full restoration treatment. Again, all tree thinning was limited to a single entry to maximize the treatment speed and minimize negative effects.

The current revision of the work plan includes two key points that affect the thinning treatments: (1) no trees over 5” in diameter will be cut, and (2) no wood will be removed from the site. These changes will have different effects at the South Rim (experimental block 2) than the North Rim (experimental block 3), because of differences in species composition and pre-treatment forest density and fuel loading.

Based on pre-treatment measurements (Ecological Restoration Program 1998), the effects of altering treatment methodologies are discussed below. These effects vary with the pre-existing condition of each experimental unit: in sites currently dominated by small-diameter young trees, such as the North Rim experimental units, the effect of a diameter limit on thinning is less than in a site with many larger-diameter young trees, such as the South Rim site. Therefore the effects of alterations to the restoration methodology will not be the same everywhere.

South Rim

The <u>minimal thinning treatment</u> at experimental block 2 (Grandview) is expected to be somewhat altered by a 5” limit on tree thinning. An average of 32.4 ponderosa pine trees per acre greater than 5” in diameter were projected to be thinned under the original proposal (Table 1, original data from pre-treatment measurements). All of these trees are less than 9” in diameter. Their retention will contribute an extra 6.42 ft^2/acre of basal area immediately post-treatment, relative to the original proposal. Assuming the average thinned tree is 3” in diameter, the thinned dry biomass per pine tree is about 15.3 lbs. If this value were similar across all species, the minimal thinning would create an additional 1.7 tons/acre of slash fuels. The 5”-9” trees projected for thinning under the original proposal would have added an additional 2.2 tons/acre of fuel. However, much of the larger thinned material could have been utilized under the original proposal and some slash would have been expected to be crushed during tree removal operations, making it less hazardous.

The <u>full restoration treatment</u> at experimental block 2 is expected to be substantially altered by a 5” limit. An average of 77.9 pines/acre, 16.7 oaks/acre, and 1 juniper/acre would be retained, for a total of 27.3 ft^2/acre above the original prescription. For comparison, this increase is equal to 105% of the *total* pre-disruption basal area (25.9 ft^2/acre) on the treatment unit. The thinned trees will contribute 0.9 tons/acre of fuel to the unit. The trees originally projected for thinning would have contributed an additional 8.5 tons/acre of fuel but much of the thinned material would have been removed from the site.

Table 1. Comparison of original and revised thinning prescriptions for the South Rim experimental block. Only woody fuels are compared because pre-existing litter and duff fuels are not affected by the thinning.

	Current tree density (trees per acre) / BA (ft^2 per acre)	**Original Rx**	**Revised Rx**	**Current fuel loading (tons per acre, not incl. litter & duff)**	**Original Rx**	**Revised Rx**
Minimal thin	566.6 / 107.2	162.4 / 86.7	194.8 / 93.1	22.4	± 24*	24.1
Intermediate restoration	332.4 / 98.3	51.1 / 64.1	146.7 / 91.4	20.6	± 24*	21.5

* Depending on the extent of wood utilization.

The effect of the revised prescriptions is beneficial in terms of site damage from mechanized equipment. No roads, skid trails, or landings would be constructed. The prescriptions are neutral in terms of added ground fuels. While extra aerial fuels still exist relative to the original prescription, the thinning of small-diameter trees helps to break up fuel ladders. In the case of the minimum thinning treatment, the 5” thinning limit has a negligible effect overall.

The forest in the intermediate restoration treatment unit, however, remains substantially more dense and with greater tree dominance than it was under the natural fire regime. Basal area would remain 350% higher and tree density 450% higher than it was prior to fire disruption. Since the initial prescribed fire will consume most of the accumulated fuels, the probability of future fire-caused mortality following the initial burn is low. There is no evidence leading one to expect that understory vegetation productivity and other ecological processes will be restored to pre-disruption conditions as long as such strikingly different tree structures persist. Therefore, the modified prescription appears likely to be inadequate as a full restoration treatment, as defined in the research proposal.

Accordingly, we recommend that the South Rim experimental block be re-assessed two years after burning to allow time for delayed mortality effects to be seen. Measurements of vegetation and fuels should be compared with the dendroecological information already assembled by the research team on the range of natural variability prior to fire regime disruption of these sites. If the data indicate that the modified intermediate restoration treatment remains inadequate, further treatment should be considered.

North Rim

The <u>minimal thinning treatment</u> at experimental block 3 (Swamp Ridge) is expected to be only slightly altered by a 5” limit on tree thinning. An average of 4.5 white fir and 6.1 Douglas-fir trees per acre greater than 5” in diameter were projected to be thinned under the original proposal (Table 2, original data from pre-treatment measurements). All of these trees are less than 12” in diameter, most less than 9”. Their retention will contribute an extra 2.5 ft^2/acre of basal area immediately post-treatment, relative to the original proposal. Assuming the average thinned tree is 3” in diameter, the thinned dry biomass per pine tree is about 15.3 lbs. If this value were similar for the North Rim species, the minimal thinning would create an additional 1.1 tons/acre of slash fuels. The larger trees projected for thinning under the original proposal would have added an additional 0.4 tons/acre of fuel. However, much of the larger thinned material could have been utilized under the original proposal and some slash would have been expected to be crushed, making it less hazardous, during tree removal operations.

The intermediate restoration treatment at experimental block 3 is expected to be moderately altered by a 5" limit. An average of 1 white fir/acre and 14.6 Douglas-fir/acre would be retained, for a total of 7.13 ft^2/acre above the original prescription. The thinned trees will contribute 1.3 tons/acre of fuel to the unit. The trees originally projected for thinning would have contributed an additional 2.2 tons/acre of fuel but much of the thinned material would have been utilized.

Table 2. Comparison of original and revised thinning prescriptions for the North Rim experimental block. Only woody fuels are compared because pre-existing litter and duff fuels are not affected by the thinning.

	Current tree density trees per acre) / BA (ft^2 per acre)	Original Rx	Revised Rx	Current fuel loading (tons per acre, not incl. litter & duff)	Original Rx	Revised Rx
Minimal thin	479.6 / 193.5	205.4 / 185.7	216 / 188.2	65.7	± 67.2*	66.8
Intermediate restoration	491.7 / 202.7	205.9 / 189.8	221.5 / 196.9	113.1	± 116.6*	114.4

* Depending on the extent of wood utilization.

The effect of the revised prescriptions is beneficial in terms of site damage from mechanized equipment. No roads, skid trails, or landings would be constructed. As suggested below, no mechanized thinning tools would be used on the North Rim site. The prescriptions are neutral in terms of added ground fuels. While extra aerial fuels still exist relative to the original prescription, the thinning of small-diameter trees helps to break up fuel ladders. In the case of the minimum thinning treatment, the 5" thinning limit has a negligible effect overall. The forest in the intermediate restoration treatment unit is also relatively similar, following thinning, to the condition originally proposed for this treatment. The post-treatment forest remains more dense than the pre-disruption forest, but continuing mortality of mid-size, fire-susceptible white fir and Douglas-fir with repeated burning is relatively much more likely than for the ponderosa pine trees on the South Rim site (see modeled mortality comparison in Appendix A).

Unlike the South Rim site, the challenges on the North Rim site have less to do with tree structure and more to do with fuel and fire management. Fuel loading is exceptionally high on the North Rim site. Since the site is also usually mesic, fire managers have found it difficult to get burning windows in which fuels are dry enough to carry fire but moist enough to prevent undesireably intense fire behavior. These issues have been discussed in a series of NPS reports (Davis 1981, Nichols 1989, Nichols et al. 1994, Botti et al. 1997).

We recommend that the North Rim experimental block be re-assessed two years after burning to allow time for delayed mortality effects to be seen. Measurements of vegetation and fuels should be compared with the dendroecological information already assembled by the research team on the range of natural variability prior to fire regime disruption of these sites. If the data indicate that the modified intermediate restoration treatment remains inadequate, further treatment should be considered.

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Appendix A: Intermediate Restoration Thinning Prescription

Ecological Restoration Marking Guidelines
for
Grand Canyon Forest Restoration Areas

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1. Objective:

Restore presettlement ponderosa pine forest structure, recreating as far as possible the density, spatial distribution, and variability of trees at the time of disruption of the frequent fire regime. Overstory structural restoration is one component of an integrated ecosystem restoration plan, which also includes forest floor fuel treatments, prescribed fire treatments, and possibly revegetation of the herbaceous understory. The rationale for such treatments is described in Southwestern Ponderosa Forest Structure: Changes since Euro-American Settlement by W.W. Covington and M.M. Moore, Journal of Forestry, 92(1):39-47 (1994) and other references.

2. Forest type:

These guidelines apply to ponderosa pine forests, with associated species including Gambel oak, pinyon, junipers, white fir, Douglas-fir, and aspen, in restoration experimental treatment areas in the Grand Canyon area, Arizona.

3. Goals:

3.1. Recreate presettlement tree density by conserving all living presettlement trees (those trees of all species established prior to the fire exclusion date) and replacing dead presettlement trees with large postsettlement trees.

3.2. Restore the patchy presettlement tree spatial pattern by retaining all living presettlement trees and locating replacement trees in the close proximity of dead presettlement trees.

3.3. Maintain a wide range of age classes by retaining all living presettlement trees, thereby conserving genetic variability to the greatest extent possible.

3.4. Maintain tree health by selecting healthy, vigorous replacement trees.

4. Marking criteria--general:

4.1. The unit boundary will be marked on border trees with orange paint or other agreed-upon mark (e.g., flagging). Three parallel lines will be painted on each border tree at breast height (4.5 ft). Marked border trees will be spaced so as to be easily visible from each other. Border trees will not be cut; therefore they should meet the leave-tree requirements listed below wherever possible.

4.2. Leave-tree marking will be used. All leave trees will be marked with a leave-tree flag at breast height (4.5 ft) and paint below stump height (1ft) on two opposite sides, preferably perpendicular to the cruising transect.

4.3. All living presettlement trees of any species will be retained.

5. Marking criteria--ponderosa pine:

5.1. All trees with yellowed bark, indicating presettlement age, will be retained. An initial training period will be needed to acquaint markers with the characteristics and variability of yellow bark. Size and age often correlate poorly in ponderosa pine, but yellow bark is a consistent sign of presettlement age in the Southwest.

Trees which are of questionable age, often those with only slightly yellowed bark, or those of large size but dark bark, should be cored to establish age with a field count of the rings. In a given area, initial coring of several questionable trees should be sufficient to train the eye to differentiate between presettlement trees and fast-growing postsettlement trees. Questionable trees should be cored at 18 in above ground level and 8 years should be added to the counted rings to estimate total age. If total age is greater than the marking year minus the settlement year (for example, 1998 - 1880 = 118 years), then the questionable tree is considered a presettlement tree.

5.2. Replacement trees will be retained for all dead presettlement trees. Evidence of dead presettlement trees includes stumps, snags, dead and downed trees, or stump holes of presettlement origin, as shown by yellow bark and large size, generally 16 in dbh or greater. A training period will be needed for markers to become familiar with the diversity of dead presettlement material, since rot, fire, and past slash treatments can affect the appearance and size of dead presettlement trees.

For each dead presettlement tree, living postsettlement trees will be retained as replacements. These trees will be selected from within a 30 ft radius of the dead presettlement tree according to the following criteria:

5.2.1. Dominants or co-dominants, minimum 6 in dbh. In a "doghair" thicket of dense, suppressed trees, only dominant trees should be selected.
5.2.2. Largest and most vigorous trees available. Retained trees may be damaged or host insects or disease, but should be apparently capable of surviving the restoration treatment (thinning, fuel treatment, burning) and living a full natural lifespan of 300+ years.
5.2.3. Timber quality characteristics such as forks, crook, sweep, dead top, lightning or fire scarring, heavy branching, etc., will *not* be considered in selecting replacement trees, except where these conditions appear to reduce the ability of the individual tree to live a full natural lifespan.
5.2.4. When the only available trees within the 30 ft radius are not acceptable replacements according to the above criteria, the search radius can be extended to 60 ft (approximately the bole length of a presettlement tree).

Because large dead presettlement trees must sometimes be replaced with small postsettlement trees, the number of replacement trees required per presettlement remnant (snag, stump, log, stumphole) will vary depending on the size of suitable replacements. Where replacements over 16" dbh are available, 1.5 such trees will replace each presettlement remnant. Where replacements are below 16" dbh, 3 such trees will replace each presettlement remnant. Biomass comparisons indicates that this ratio will maintain an adequate replacement foliage, bark, and branch biomass. However, excess tree density in areas of small replacement trees will require future treatments (e.g., snag creation) after 10-20 years.

5.3 If one or more dead presettlement trees cannot be replaced within the 30-60 ft search radius, the following procedure will be used to ensure that the presettlement tree or group is retained as forest rather than converted to a grassy opening: (1) locate the site on a sketch map of the treatment unit and assign a group ID number; (2) note the number of trees in the group; (3) leave a wire flag at the site with the group ID number; and (4) after marking, replace the wire flag with a permanent post (such as a fencepost) and ID tag. These sites will be replanted after the restoration treatment.

6. Marking criteria--other:

6.1. Gambel oak: living presettlement oaks will be retained. Gambel oak often develops heartrot and cores can be difficult to date, but generally oaks over 10 in dbh are of presettlement origin. Where evidence of dead presettlement oaks is found, the 2 largest replacement trees within a 15 ft radius should be retained. A well-established oak clump (several stems > 8 in dbh) can be taken as evidence of presettlement oak presence even in the absence of a large dead stem, because the central stem could have rotted away but the clump often persists over time and maintains the clonal genotype through sprouting. Replacement trees should be vigorous and appear likely to survive to a full natural lifespan. Deficiencies in replacements should be made up as quickly as possible. When a large contiguous clump is encountered, divide it into 12 ft units and treat each separately for marking purposes.

6.2 Juniper and Pinyon: living presettlement junipers (all species) and pinyon will be retained. Juniper cores are often difficult to extract and date, but in general junipers over 12 in drc [*diameter root collar*] and pinyons over 10 in dbh are of presettlement origin. Where evidence of dead presettlement juniper or pinyon trees is found, the 2 largest replacement trees within a 15 ft radius should be retained. Replacement trees should be vigorous and appear likely to survive to a full natural lifespan. Deficiencies in replacements should be made up as quickly as possible.

6.3 Douglas-fir and white fir: living presettlement trees will be retained and replacements for dead presettlement trees will be selected following the guidelines for ponderosa pines. Trees should be cored during an initial training period to establish a general age-diameter relationship.

6.4 Aspen: no aspen will be cut or marked.

Appendix B: Minimal Thinning Prescription

Introduction

The minimal thinning treatment is described briefly in the project proposal as follows (Covington et al., Grand Canyon Forest Ecosystem Restoration Proposal, revised June 12, 1997, page 15): *The minimal thinning treatment will be the same as the full restoration treatment* [i.e., restoration of structure, function, etc.], *except that thinning will be carried out only to the extent necessary to break up fuel ladders or remove small trees from around presettlement trees.*

This treatment is new, in contrast to the full restoration treatment which has been implemented at various sites and scales for several years. Therefore the treatment rationale is described in detail below. The prescription specifics are likely to change as its theoretical and practical aspects are evaluated with experience over time.

The minimal thinning treatment is intended to help meet restoration goals at an intermediate level between the intermediate restoration of ecosystem structure and the burn-only treatment. The intermediate restoration treatment creates forest structures which emulate those of presettlement ecosystems as closely as possible within the constraints of the study sites and the upper limit on thinning diameters. The effects of such treatments are reviewed in Covington et al. (1997) and Fulé et al. (1997). The burn-only treatment removes accumulated fuels and affects forest structure to a limited degree, but some of these effects may be deleterious to remaining presettlement ecosystem components (e.g., the NWIII prescribed fire on the North Rim killed a number of presettlement trees as well as understory plants and led to soil erosion in some areas, due to the heavy fuels and dense overstory). The long-term effects of re-introducing fire into a highly altered ecosystem is uncertain, but the burn-alone treatment is unlikely to significantly alter forest density, herbaceous production and diversity, or the competition between trees which is causing decreased growth and increased mortality among presettlement trees (Biondi et al. 1994, Covington and Moore 1994, Sackett et al. 1996, Covington et al. 1997).

The minimal thinning treatment will help conserve key ecosystem elements, such as old-growth trees, for some period of time into the future. Advantages to the minimal thinning approach include: (1) reduced short-term treatment impacts on soils, understory vegetation, wildlife habitat, and esthetic values because of the reduced scale of thinning and wood removal operations; and (2) lower short-term costs, also due to the reduced scale of operations. Disadvantages to the minimal thinning approach include: (1) perpetuation of unnatural forest ecosystem structure, continuing the disproportionate dominance of trees relative to herbaceous plants and shrubs, implying that the normal ecological structures, functions, and habitats of the evolutionary environment will not be restored; and (2) maintaining an ecosystem which is still subject to catastrophic change, such as high-intensity wildfire, large-scale pathogenic outbreaks, or excessive mortality of old-growth trees, although certainly at a reduced level of risk compared to typical contemporary conditions. In sum, the minimal thinning treatment will substantially improve ecosystem health (see Kolb et al. 1994 for discussion of ecosystem health concepts). But wherever the management goal is to restore natural ecosystems, as is the case for many parks, wilderness areas, or natural areas, the minimal thinning treatment should be viewed as a stopgap measure to forestall the imminent loss of the slowest ecosystem variables such as old-growth trees and the soil erosion which follows high-intensity wildfire. The minimal thinning treatment can buy time, but in itself it is not a comprehensive ecological restoration treatment.

Rationale

Vulnerability to catastrophic changes, those which fall substantially outside the natural range of variability in ecosystem dynamics and natural disturbance processes, is an indicator of degraded ecosystem health (Kolb et al. 1994). Southwestern forests—as well as many frequent-fire-adapted forests throughout western North America—are vulnerable to novel high-intensity disturbance regimes, especially crownfire (Covington et al. 1994). The central idea of the minimal thinning treatment is to reduce the risk of mortality for the presettlement trees which are the slowest organismic variables in the ecosystem. These trees are threatened primarily by direct effects of wildfire and by increased mortality associated with competitive stress. This stress increases the susceptibility of trees to injury and mortality from pathogenic plants (e.g., dwarf mistletoe), animals (e.g., bark beetles), and abiotic agents (e.g., lightning, drought) by reducing the capability of trees to recover from these injuries. Thinning reduces the risk of crownfire, by removing fuel ladders and interlocking canopies. At the same time, thinning reduces the effects of competition by removing younger competing trees.

Defining a minimal level of thinning is based on the sources of mortality which affect the presettlement trees. Trees can be injured or killed by (1) crownfire which consumes or heavily scorches the canopy; (2) intense local fire behavior, including heavy scorch, bole char, or torching, at a level below crownfire; and (3) basal injury from smoldering duff (Ryan and Frandsen 1991, Sackett et al. 1996). Category (3) is covered by the old-tree protection treatment of removing accumulated duff from around the tree bole. Categories (1) and (2) are addressed in the minimal thinning prescription. Other sources of mortality, including stress due to competition from dense younger trees, insects, and disease, is discussed below.

Crownfires can be prevented by reducing forest canopy to the point that fire cannot pass through the tree crowns (even though individual trees or groups can torch). The change can be expressed as moving from a fire behavior fuel model 9, appropriate for closed ponderosa pine forests, to a fuel model 2, which is a grass-dominated open forest (Anderson 1982). Grass-dominated fuelbeds support high rates of spread and relatively high flame lengths, but the flaming front moves swiftly. In contrast, the litter and woody fuels which carry the fire in a timber-dominated fuelbed support a longer residence time for both flaming and smoldering combustion. Extended periods of intense heating have greater effects on plants, soils, and smoke production. Where aboveground fuels exist, extended heating by ground fuels can preheat fuel ladders into the canopy and permit torching and/or crownfire behavior to develop. Presettlement ponderosa pine forests are described by fuel model 2, while most contemporary ponderosa forests fall into fuel model 9 (Covington et al. 1997). A full restoration treatment is designed to emulate presettlement structure, so the risk of crownfires is essentially eliminated (even though individual trees or groups may still torch under extreme fire conditions). In a minimal thinning treatment, the concept is more limited: reduce density around *individual presettlement trees or groups of trees* sufficiently to change the immediate surroundings of the tree from a closed forest which can sustain crownfire (fuel model 9) to an open forest which cannot (fuel model 2). Beyond simply preventing crownfire, however, the potential for sub-crownfire behavior (torching, heavy scorch, bole char) around these trees must be reduced to the point of greatly increasing their chances of survival.

A **conceptual design** of a minimal thinning treatment based on the above discussion is outlined next:

1. Thinning is targeted around individual presettlement trees—the "target" trees. Fuel structures need to be designed so that crownfire cannot cross to the target tree and the fire intensity of any wildfire at that tree is low enough to avoid mortality. Prescribed fire is an integral component of a minimal thinning treatment.
2. To prevent crownfire, timber fuel models (usually fuel model 9, other possibilities are 8 or even 10—see Anderson 1982) must be converted to grass-savanna fuel models (fuel model 2) in the vicinity of the tree. Fuel ladders and dense stands with interlocking canopies need to be thinned intensely around the target tree, then progressively less intensely moving away from the target tree.
3. To prevent excessive fire behavior (not crownfire) around the target tree, nearby trees and heavy ground fuels (woody and duff) must be cleared immediately around the tree.
4. To be consistent with general restoration goals, thinning should focus on the smallest and youngest trees. Presettlement trees will not be thinned. Wherever possible, the largest trees should be left, especially where such trees would have been selected as replacements for dead presettlement trees in a full restoration prescription. In no case should *more* trees be thinned under the minimal thinning prescription than would have been removed under a full restoration prescription.

5. The decision whether or not to remove any of the thinned material will be site-specific and related to the costs, complexity, and value of the thinned material. In many or most cases, a non-commercial approach to minimal thinning probably will make the most sense.
6. Future changes in the condition of the treated area need to be considered. Because most of the unthinned trees will be large enough to survive prescribed fires and many wildfires, their continued and accelerated growth in the thinned stand will tend to increase fire and competitive hazards for the target tree over time.

To move from a conceptual design to an operational prescription, quantitative values must be attached to the structural characteristics described above. Our approach has been to develop a preliminary prescription based on modeling of fire behavior and fire effects, together with empirical input from fire managers.

Modifying fire behavior around the target tree:

Models have been developed to quantify the probability of mortality associated with varying degrees of fire intensity (flame length, scorch height). Tree susceptibility has been found to vary with species, bark thickness, and diameter (Ryan and Reinhardt 1988, Ryan et al. 1988). Models can be useful to help express trends and differences, but real situations are likely to be highly variable. In addition, factors not included in the model, such as burning season, may be highly important in determining actual fire effects (Harrington 1985, 1987).

The First-Order Fire Effects Model (FOFEM) developed by Reinhardt et al. (1995) was used to project fire behavior variables associated with increasing probabilities of mortality. Results are presented below for all the Grand Canyon species which are available in the program, using a range of diameters associated with presettlement or old-growth trees of these species.

Modeled Mortality Probability Associated with Fire Behavior

Model used: First-Order Fire Effects Model (FOFEM), Individual Tree Mortality model

Model conditions: tree height 60', live crown ratio 40% (aspen and ponderosa) or 80% (Douglas-fir and white fir), fire severity class "high", cover type SAF 237 (Interior Ponderosa Pine)

Species	Size (dbh, inches)	Probability of Mortality associated with FLAME LENGTH (ft)			Probability of Mortality associated with SCORCH HEIGHT (ft)		
		0%	15%	50%	0%	15%	50%
Aspen							
	10	0.1*	0.1	0.1	0.1*	0.1	1.4
	15	0.1	0.1	0.6	0.2	0.4	3.8
	20	0.1	0.2	1.1	0.2	2.4	6.6
Douglas-fir							
	15	0.1	3.3	4.7	0.2	17.6	30.2
	20	0.1	4.0	5.1	0.2	23.4	34.0
	25	0.1	4.3	5.4	0.2	26.6	36.8
Ponderosa pine							
	15	0.1	0.1	6.1	0.2	0.2	44.0
	20	0.1	5.8	6.3	0.2	40.6	46.2
	25	0.1	6.0	6.5	0.2	42.4	47.6
White fir							

	15	0.1	0.1	4.1	0.2	0.2	24.4
	20	0.1	0.1	4.5	0.2	0.2	28.4
	25	0.1	3.6	4.9	0.2	20.0	31.4

* *Flame lengths or scorch height of 0.1 mean the model predicts that ANY fire will exceed the mortality probability level (e.g., 0%).*

There are three major trends in the model results: (1) there is always at least *some* probability of mortality associated with fire, even at very low intensities; (2) species are substantially different in fire susceptibility, with ponderosa pine the most resistant, followed by Douglas-fir, white fir, and aspen; and (3) within species, large-diameter trees are more resistant than small-diameter trees. The values of flame length and scorch height indicated by the model are useful mostly as a guide in assessing the relative susceptibility of different trees. In practice, trees of these species in these size classes have a very high probability of surviving routine prescribed burning in the Southwest, even though typical flame lengths are higher than the minimums listed above. Three groups of tree species found at Grand Canyon are not included in the FOFEM model: Gambel oak, junipers, and pinyon pine. These are relatively fire-susceptible trees, probably falling somewhere between aspen and white fir with respect to the survival probabilities modeled above. Gambel oak and junipers are particularly vulnerable to cambial girdling from basal heating.

The first step in thinning is to mark the intermediate restoration prescription on the minimal thinning treatment. This mark will (1) ensure that all living presettlement trees are identified and retained; and (2) identify postsettlement replacement trees which will not be removed during the minimal thinning treatment. The intermediate restoration mark provides a baseline template for the minimal thinning treatment. In contrast to the intermediate restoration treatment, however, not all of the unmarked trees in the minimal thinning treatment will be removed. Instead, some of them will be removed according to the following guidelines.

To minimize fire behavior around the target tree, thinning intensity must be greatest close to the tree. Different thinning intensities in three concentric circles or ellipses around each tree alter fuels to break the intensity of fires to permit the target tree to survive.

The maximum distance for thinning is related to the highest intensity of fire behavior (crownfire) that can kill the target tree. Torching and crownfire behavior are possible beginning at fireline intensities of 1,000 BTU/ft-s (3,460 kW/m) or flame lengths of 20' (6.1 m) and increasing up to flame lengths of several times canopy height (Rothermel 1991). Crownfire behavior is highly variable and difficult to predict because it is driven by wind and moisture conditions (see discussion and references in Rothermel 1991, and FARSITE [1997] technical documentation), but a practical thinning prescription must be based on reasonably objective and consistent characteristics that can be observed in the field. Therefore, the average height of the canopy within 40' (approximately 12 m) surrounding the target tree is proposed as the maximum thinning distance, with a minimum of 40'. If the average canopy height is 50', for example, thinning would extend out to 50' from the target tree. In the outer circle--between 30 and 50'--the thinning intensity would be least. The goal of thinning in this area is to create a transition between the surrounding forest (fuel model 9) and the inner thinned circle (fuel model 2). Although fewer trees would be removed, thinning would still focus on breaking up fuel ladders and separating groups of trees.

From about 15' to 30' (approximately 5 to 10 m) from the target tree, the goal is to create a grass/savanna fuel model similar to the presettlement forest. Thinning in this area will remove many to all of the unmarked trees. At this level of thinning, more trees may be retained than in the closest circle. Trees may be retained individually or in groups. Fuel ladders must be removed.

In the area closest to the target tree, within approximately 15' (approximately 5 m), surrounding trees should be thinned heavily, especially those with interlocking crowns and shorter trees which contribute to fuel ladders. Only the presettlement trees and marked replacement trees will be retained. Forest floor fuels must be raked away from the target tree bole as described in the old-tree protection methods. In addition, other large fuels or slash must be pulled away from below the target tree crown.

Thinning patterns need to be adjusted for slope and wind direction to account for more intense fire behavior as fires move upslope and with the wind. The distance of each thinning level can be extended about 15-30% in the downslope direction from the target tree, for slopes > 10%, and in the upwind direction of the prevailing fire season winds (W and S). Corresponding reductions can be made in the upslope and downwind (N and E) directions.

Selection of residual trees (apart from presettlement trees of all species, all of which are retained) should favor larger, older trees, which appear capable of surviving for a normal lifetime. Except where the following conditions seem likely to cause premature mortality, candidate trees should *not* be cut due to species, tree form, disease, herbivory, or damage from lightning, wind, or snow. Species composition in the residual trees should favor the presettlement composition, as observed from the living and dead presettlement trees on the site. In practice, this will probably mean proportionately higher cutting of white fir, the primary invading species on the experimental blocks. The most fire-susceptible species, aspen and Gambel oak, will not be thinned (except for small trees which clearly contribute to a fuel ladder). As with the intermediate restoration prescription, the density of oak will be re-assessed after the first prescribed burn and oaks can then be thinned if necessary.

Carrying out the minimal thinning prescription in the field is more complex than for a typical thinning operation. Typical forest management thinning practices are fairly mechanistic because the goal is usually an even spacing of residual trees. Therefore, the first step in this treatment is to mark trees with the intermediate restoration prescription. Then, to handle the complexity of the treatment in an efficient manner, two-person thinning crews are suggested. The two crew members would work together, with one person taking the role of selecting residual trees beyond those already marked, keeping in mind the various considerations of distance, canopy height, etc., while the other person thins the trees.

Future effects of the minimal thinning treatment:

Short-term survival of the target presettlement trees is likely to increase under the thinning treatment, not only due to the reduced risk of fire mortality but also to the altered forest structural conditions. Competition from trees surrounding the presettlement trees will be reduced. Presettlement ponderosa pines at the Gus Pearson Natural Area, under a full restoration treatment, showed a rapid response (< 3 years) to thinning with decreased water stress, increased photosynthesis, increased herbivore resistance (higher resin flow and needle toughness) (Covington et al. 1997). The minimal thinning treatment would be likely to cause a smaller response but following the same trend. In general, thinning is expected to increase residual tree growth (Schubert 1974, Ronco et al. 1985) and decrease the risk of bark beetle outbreaks (Olsen et al. 1996). Root rot fungi could spread in thinned stumps, especially in the mixed conifer site. Considerations relating to root rot are discussed under 'stumps' (above). The higher vigor of the presettlement trees following thinning should increase their ability to resist or recover from attacks by pathogens or abiotic damage (lightning, wind, snow, fire), but this factor will have to be observed over time.

The long-term survival of the presettlement trees, however, may not be enhanced by a single minimal thinning treatment and repeated prescribed fire. The residual postsettlement trees will also grow quickly in the thinned environment and will renew competitive stresses on the presettlement trees. These young trees will probably have only minor thinning from prescribed fire (Sackett et al. 1996). Increased tree growth will minimize the recovery of the herbaceous and shrub understory. Ultimately, tree canopies will re-close and the fire hazard to the presettlement trees will reappear. Continued management entries would be required to maintain the short-term minimal thinning effects. For these reasons, the minimal thinning treatment should be viewed as a temporary response to the impending loss of the remaining presettlement trees, rather than as a comprehensive approach to ecosystem restoration.

Implementation and review:

The minimal thinning treatment should be tested and reviewed on the ground by researchers and agency staff. Modifications are likely. Prior to thinning of any trees, a demonstration area of approximately 3 acres (1 ha) will be completely marked with flagging, including the intermediate restoration mark as well as the additional residual trees under the minimal thinning guidelines. This demonstration area will be useful to resolve problems and make changes, present the concept for review, and train operators.

Prescription

Minimal Thinning Guidelines
for
Grand Canyon Forest Restoration Areas

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December 1, 1997 (version 1)

1. Objective:

The minimal thinning treatment is intended to help meet restoration goals at an intermediate level between the full restoration of ecosystem structure and the restoration of fire alone. It will help conserve key ecosystem elements, such as old-growth trees, for some period of time into the future but should be viewed as a stopgap measure to forestall the imminent loss of the slowest ecosystem variables such as old-growth trees and the soil erosion which follows high-intensity wildfire. The minimal thinning prescription is one component of a broader ecosystem treatment, which also includes forest floor fuel treatments, prescribed fire treatments, and possibly revegetation of the herbaceous understory.

2. Forest type:

These guidelines apply to ponderosa pine forests, with associated species including Gambel oak, pinyon, junipers, white fir, Douglas-fir, and aspen, in restoration experimental treatment areas in the Grand Canyon area, Arizona.

3. Goals:

3.1. Alter fuel structures so that crownfire is unlikely to cross to the presettlement trees and so the fire intensity of any wildfire at each presettlement tree is low enough to avoid mortality.

3.2. Consistent with general restoration goals, thinning will focus on the smallest and youngest trees. Presettlement trees will not be thinned. Wherever possible, the largest trees will be left, especially where such trees would have been selected as replacements for dead presettlement trees in a full restoration prescription.

3.3. Maintain a wide range of age classes by retaining all living presettlement trees, thereby conserving genetic variability to the greatest extent possible.

3.4. Maintain tree health by selecting healthy, vigorous replacement trees.

4. Marking criteria--general:

4.1. The unit boundary will be marked on border trees with orange paint or other agreed-upon mark (e.g., flagging). Three parallel lines will be painted on each border tree at breast height (4.5

ft). Marked border trees will be spaced so as to be easily visible from each other. Border trees will not be cut; therefore they should meet the leave-tree requirements listed below wherever possible.

4.2. Leave-tree marking will be used. All leave trees will be marked with a leave-tree flag at breast height (4.5 ft) and paint below stump height (1ft) on two opposite sides, preferably perpendicular to the cruising transect.

4.3. All living presettlement trees of any species will be retained.

5. **Tree marking:**

5.1. All presettlement trees and replacement trees for dead presettlement trees will be identified and marked following the intermediate restoration prescription before beginning thinning operations. The living presettlement "target trees" will be the focus of thinning to reduce fire behavior around them. Rules for identifying presettlement trees are listed below.

Ponderosa pine. All trees with yellowed bark, indicating presettlement age, will be retained. An initial training period will be needed to acquaint markers with the characteristics and variability of yellow bark. Size and age often correlate poorly in ponderosa pine, but yellow bark is a consistent sign of presettlement age in the Southwest. Trees which are of questionable age, often those with only slightly yellowed bark, or those of large size but dark bark, should be cored to establish age with a field count of the rings. In a given area, initial coring of several questionable trees should be sufficient to train the eye to differentiate between presettlement trees and fast-growing postsettlement trees. Questionable trees should be cored at 18 in above ground level and 8 years should be added to the counted rings to estimate total age. If total age is greater than the marking year minus the settlement year (for example, 1995 - 1870 = 125 years), then the questionable tree is considered a presettlement tree.

Gambel oak. Gambel oak often develops heartrot and cores can be difficult to date, but generally oaks over 10 in dbh are of presettlement origin. A well-established oak clump (several stems > 8 in dbh) can be taken as evidence of presettlement oak presence even in the absence of a large dead stem, because the central stem could have rotted away but the clump often persists over time and maintains the clonal genotype through sprouting.

Junipers and pinyon. Juniper cores are often difficult to extract and date, but in general junipers over 12 in drc [*diameter root collar*] and pinyons over 10 in dbh are of presettlement origin.

Douglas-fir and white fir. Trees should be cored during an initial training period to establish a general age-diameter relationship.

Aspen. Even large-diameter aspen trees are usually not of presettlement age, but their presence commonly indicates the site of an aspen clone which may be extremely old. Individual aspen stems will not be marked with flagging, but aspen will not be thinned in this treatment.

6. **Thinning criteria:**

6.1. Thinning intensity will vary around each presettlement target tree, with three different levels of thinning at radii of (1) 15', (2) 15 to 30', and (3) 30' to the maximum thinning distance.

6.1.1. Within a radius of 15', only the presettlement trees and marked replacement trees will be retained. Forest floor fuels must be raked away from the target tree bole as described in the old-tree protection methods. In addition, other large fuels or slash must be pulled away from below the target tree crown.
6.1.2. Between 15 and 30', the goal is to create a grass/savanna fuel model similar to the presettlement forest. Thinning in this area will remove many to all of the unmarked trees.

At this level of thinning, more trees may be retained than in the closest circle. Trees may be retained individually or in groups. Fuel ladders must be removed.

6.1.3. The maximum thinning distance is equal to the average height of the canopy within 40' surrounding the target tree, with a minimum of 40'. If the average canopy height is 50', for example, thinning would extend out to 50' from the target tree. In the outer circle--between 30 and 50'--the thinning intensity would be least. The goal of thinning in this area is to create a transition between the surrounding forest (fuel model 9) and the inner thinned circle (fuel model 2). Although fewer trees would be removed, thinning would still focus on breaking up fuel ladders and separating groups of trees.

6.1.4. Thinning patterns need to be adjusted for slope and wind direction to account for more intense fire behavior as fires move upslope and with the wind. The distance of each thinning level can be extended about 15-30% in the downslope direction from the target tree, for slopes > 10%, and in the upwind direction of the prevailing fire season winds (W and S). Corresponding reductions can be made in the upslope and downwind (N and E) directions.

6.2 Criteria for selecting residual trees (other than those already marked following the intermediate restoration prescription):

6.2.1. Dominants or co-dominants, minimum 6 in dbh. In a "doghair" thicket of dense, suppressed trees, only dominant trees should be selected. Depending on their proximity to the target trees, some or all of the smaller trees creating a fuel ladder may be thinned.

6.2.2. Largest and most vigorous trees available. Retained trees may be damaged or host insects or disease, but should be apparently capable of surviving the restoration treatment (thinning, fuel treatment, burning) and living a full natural lifespan.

6.2.3. Timber quality characteristics such as forks, crook, sweep, dead top, lightning or fire scarring, heavy branching, etc., will *not* be considered in selecting replacement trees, except where these conditions appear to reduce the ability of the individual tree to live a full natural lifespan.

6.2.4. Species composition in the residual trees should favor the presettlement species mix, as evidenced by living and dead presettlement trees on the site.

6.2.5. All aspen or Gambel oak will be retained, except if small trees of these species are creating a fuel ladder into a presettlement tree.

7. Thinning procedure:

7.1. Thinning should be done in two-person crews following flagging of all the presettlement trees. Two people are needed because of the complexity of the prescription. One person is in charge of selecting trees to be retained, bearing in mind the factors of distance, density, topography, etc., and assisting with spotting (serving as a safety observer during felling) and swamping (pulling branches out of the way after the sawyer cuts them) operations. The second person will thin the trees. The crew members should switch tasks periodically.

7.2 Thinning slash should be lopped to 4' lengths and scattered. Slash should not be permitted to accumulate next to presettlement trees, fire-susceptible residual trees (especially oak, aspen, juniper, and true firs), or on other fire-sensitive plants designated on a site-specific basis.

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APPENDIX D
FOREST ECOSYSTEM RESTORATION RESEARCH
PUBLIC COMMENT AND NPS RESPONSE

Public concern about the Draft Forest Restoration Environmental Assessment (January 1999) and the associated research proposed for Grand Canyon National Park resulted in about 300 written and e-mail comments. Many of the comments received apparently resulted from letter writing campaigns initiated by national groups. A majority of the respondents were willing to consider the merits of the research project and many were opposed to commercial logging and tree cutting within the North Rim proposed wilderness site. Below are National Park Service (NPS) responses to 50 specific public comments organized under ten general headings. Headings 1 to 7 are thinning topics, heading 8 is a fire topic, and headings 9 to 10 are public involvement and compliance topics.

<u>Thinning Topics</u>

1. Oppose all experimental treatments.

- *Public Comment:* Experimentation should be done outside the Park or on less sensitive lands.
  NPS Response: Timber harvesting, livestock grazing, and fire suppression activities have been applied to forestlands adjacent to Grand Canyon National Park. Other test sites were considered, but no sites were found with comparable forest conditions, species composition, stand density, climate, soils, etc., and having equivalent baseline documentation. Park lands differ from surrounding lands in that they have more old growth trees, severe ground and ladder fuels, few emergency access roads, different land use histories, and different management policies. Although parklands have had minimal grazing during the 1920-30s and fire suppression activities have been conducted since the 1920s, the above-mentioned factors make forest restoration research conducted at Grand Canyon unique. Also**,** the research sites would receive long-term protection because the research project lies within Park boundaries. Three sites were chosen for this work, including two within the Park and one on South Kaibab National Forest lands. The North Kaibab District was invited as a cooperator, but could not participate because of prior commitments during the time frame of this work. The research sites would also help inform future Park management decisions. Forest response to similar restoration treatments outside the Park may differ from Park sites. Research results from other areas may not be applicable to the Park's forested lands.
- *Public Comment:* Research project should be stopped.
  NPS Response: NPS policies encourage management decisions based on the best available scientific information. Grand Canyon National Park finds that the research project would benefit Park resources, purposes, and values. Forest restoration research provides site-specific information to address the Park's goal to reduce the risk of stand-replacing wildfires and their associated human and resource impacts, and improve forest ecosystem process and function. This data is urgently needed for Park resource management planning, including future revisions of the Fire Management Plan and the Resource Management Plan. This research will provide information and test methods to reestablish periodic low-intensity natural fire, increase the vigor and longer survival of presettlement or old growth ponderosa pine trees, and increase the diversity of native, understory forest plants and animal life. These efforts would gradually re-establish a more natural wild forest condition on the study plots over a period of several years, improve the knowledge of forest ecology, and yield more appropriate resource management options. To delay development and testing of improved management practices increases the probability of large-scale wildfire damage in the future. Experimentation provides a way of testing alternative management strategies on a small, well-controlled scale, where they can be scientifically evaluated.
- *Public Comment:* Park lacks long-term ecological goals.
  NPS Response: Long-term ecological goals must be based in the best available science and a responsive adaptive management plan. Currently Grand Canyon National Park is guided by NPS resource management policies (NPS-77, 1991), a General Management Plan (1995), and a Resource Management Plan (1997). In the future, Grand Canyon National Park will be revising the Fire Management Plan and other media plans. Upon completion of the forest restoration and other related research projects, the information gathered would better enable Park mangers with public involvement to define the desired future conditions of the forested lands through a public involvement process. A proposed management action would list a set of alternatives that in turn would have a suite of desired

responses. The desired condition of a forested area is the condition of a resource anticipated to be brought about by a land management action. Currently, the ability to describe desired conditions is hampered by limited or incomplete information on the range of natural variability. It is also import to model how the forest ecosystems might look today were they not impacted by turn of the century livestock grazing and subsequent exclusion of fire.

- *Public Comment:* Allow nature to take its course. Just leave it alone.
  NPS Response: The NPS is mandated to preserve park resources for the enjoyment of current and future generations. The Park cannot stand back and allow "nature" to take its course. Natural processes have been altered by extensive turn of the century livestock grazing, predator control, deer herd irruption, fire suppression activities, growth of mixed conifer under the ponderosa pine overstory, canopy closure, loss and reduction of meadows and understory plants, habitat fragmentation, and possible regional climatic changes. The size, severity, and frequency of large-scale wildland fire appear to have been on the increase in the region. Severe wildfires have destroyed large areas of the North Rim forests in 1996 and 2000. To do nothing would invite the increased risks of stand-replacing fire and its associated human and resource impacts.
- *Public Comment:* Little trust in the action of federal agencies.
  NPS Response: The National Environmental Protection Act (NEPA) of 1969 requires a process that helps government agencies to make better decisions. It allows environmental information to be available to the pubic and land management officials before decisions are made and before actions are taken. It not only allows public officials to approve or reject a specific project, but it also helps to mitigate, lessen or avoid adverse environmental consequences. Through NEPA, the public can become involved, reasonable alternatives are developed, and impacts to the environment are analyzed. Measures can be developed to mitigate human and resource issues. The agency can then weight this information with economic and political factors to make an informed decision. Grand Canyon National Park has worked within NEPA regulations by holding a March 1998 workshop, issuing an April 1998 scoping letter to interested parties, distributing a January 1999 draft Environmental Assessment, and holding pubic meetings on February 11, 1999 in Flagstaff and Feburary 12, 1999 in Kanab, Utah. Issues brought about by public comment letters have been addressed by the revised August 1999 work plan, a further revised October 2000 work plan, and this Environmental Assessment. A 30-day public comment period will solicit public input and review on this Environmental Assessment.

2. Oppose tree cutting in the North Rim proposed wilderness.

- *Public Comment:* Not in a proposed wilderness area.
  NPS Response: While there is opposition to thinning in the North Rim proposed wilderness; work within the proposed wilderness is urgently needed. Fuel loading is exceptionally high on the North Rim study site. Future designation for a proposed wilderness area would not be affected by tree thinning as prescribed by the research program on the 40 acres on the North Rim research site. Work within the area proposed and managed as wilderness would follow current minimum requirement process established by the NPS and Park policies. Hand tools would be used to mitigate the public's concern about the use of mechanized equipment, noise, and safety concerns. Current NPS policies regarding designation of wilderness areas say that an area should not be excluded just because it needs restoration or rehabilitation (NPS RM-41:6.2.1). Trees have been cut in other designated and proposed wilderness areas in the United States.
- *Public Comment:* More data needed from elsewhere before continuing.
  NPS Response: Park management strongly supports data collection. The severely altered conditions of Grand Canyon's forests and the potential for catastrophic wildfire have been documented through numerous reports for at least 20 years. The management approaches being tested in this experiment have also been recommended in at least four agency reports since 1989. Forest restoration projects are being conducted outside Grand Canyon National Park (Appendix G). These projects include the Fort Valley Urban/Wildland Project, the G. A. Pearson Natural Area, Williams Restoration Demonstration Project, the Taylor Woods Thinning Study, the Chimney Springs Interval Burn Site, and the Tusayan Ranger District Forest Restoration (the site adjoining the South Rim's Grandview site). Results and analysis of these projects along with that of the proposed Northern Arizona University research would be reviewed and incorporated into future Park management planning. This small-scale research project would not be expanded to other areas within the Park without additional environmental compliance and public involvement.

3. Oppose commercial logging.

- *Public Comment:* No logging in a National Park.
  NPS Response: Logging is defined as the work or business of felling trees and conveying the logs to a mill. This research project is not removing trees from the study site, taking them to a mill, or deriving any economic benefit through the sale of the milled timber. No roads would be built or improved, there would be no skid trails or landings, and no logging trucks would remove wood from the research site.
- *Public Comment:* Action is precedent setting.
  NPS Response: The action of this proposed research would not be precedent setting. This project would follow current NPS guidelines guiding administrative and research activities within proposed wilderness areas. Large-scale forest thinning has been practiced on many Federal forested areas for many years under the objective of research and tree thinning. Other NPS units have felled larger areas of trees for a variety of purposes. These include boundary fuel reduction activities for fire protection, removal of burned trees following wildfire events, maintaining scenic vistas or view sheds, treatment of trees which have been killed by insects, diseases, mistletoe infestation, and weather or geologic events, hazard trees, tree removal to maintain critical habitat for endangered species, removal of non-native trees, thinning to effect a type conversion in the woodland (i.e., remove trees to restore grasslands or meadows), attempts to stop soil erosion by encouraging understory plant growth, and activities prior to prescribed burning treatments. The NPS has encouraged scientific studies for many years. The protection of scientific values was also included in the Park's authorizing legislation.
- *Public Comment:* No commercial logging or wood sales.
  NPS Response: The work plan states that only trees with a dbh of 5-inches or less would be cut and these would be left on site. No wood would be removed from the site, taken to a mill, or sold for any purposes.
- *Public Comment:* Forest structure destroyed by logging methods.
  NPS Response: No logging methods (i.e., feller buncher, helicopter logging, log landings, decking, or removal) would be used by this research proposal. The current forest structure is not natural. Forest structure has been degraded since the turn of the century by fire suppression activities, becoming dense and less park-like. Tree growth has been compromised by competition for nutrients. Lack of light and accumulation of leaf and branch litters have degraded understory plant and animal communities. This project would begin to restore more natural forest conditions to the study sites and maintain old-growth trees.
- *Public Comment:* Roads should not be used during goshawk nesting and fledging periods (approximately March 15 to September 30).
  NPS Response: The research study sites are located along open public roads. The project would not expand the road network or substantially increase traffic. Goshawk surveys by Park wildlife staff during 1997, 1998, and 2001 have found no goshawk nests in the experimental study plots on North or South Rims. While goshawks are known to nest outside the region surrounding the plots, biologists have confirmed a no effect on this species by the proposed action. Protection of the Mexican spotted owl is also taken into account. Surveys of the North and South Rim study sites have found no nests or owl response during 1998,1999, 2001.
- *Public Comment:* Concerns regarding techniques and equipment proposed in the draft Environmental Assessment.
  NPS Response: The revised work plan (October 2000) responds to public comment. There would be no use of logging methods by the proposed action. Only trees with a dbh of 5-inches or less would be cut and then dispersed on the site. On the South Rim the trees would be cut with chain saws and hand tools would be used on the North Rim. Job hazard analysis would be complete prior to treatment.
- *Public Comment:* Concerns about the removal of biomass.
  NPS Response: No biomass would be removed during the proposed treatments. All material would be left on site. Over time, prescribed burns will consume all material that has been lopped and scattered or stacked in piles.
- *Public Comment:* Concerns about the impacts caused by from log landings.
  NPS Response: Log landings are open areas where logs or other forest materials are brought together and stored until they can be removed from the site. There would be no log landings or associated impacts created by this proposed research, as material would be left on site.
- *Public Comment:* Concerns about the impacts caused by building and improving roads.

- *NPS Response:* The treatment blocks were purposely located nest to existing roads in order to avoid any new road construction and none of the existing roads will be upgraded.
- *Public Comment:* Use minimal tool (i.e., horse logging vs. mechanical harvesting).
  NPS Response: The minimal tool analysis has been completed and is incorporated into this Environmental Assessment. No logs will be removed from the site, so horse logging would not be needed. No mechanized equipment would be used for thinning on the North Rim site, proposed for wilderness status. On the South Rim, thinning will be done with chainsaws .

4. Oppose the full restoration treatment.

- *Public Comment:* Full restoration thinning is too drastic or extreme.
  NPS Response: The "full restoration" prescription is not part of this project. The revised work plan (October 2000) replaces the "full restoration treatment" with a less intensive "intermediate restoration treatment." It eliminates cutting of trees larger than 5-inches dbh, except as needed to mitigate specific safety hazards. There would be no use of heavy, mechanized equipment or logging methods.
- *Public Comment:* Presettlement model is not justified.
  NPS Response: A model is a tentative description of a theory or system that accounts for all of its known properties. Grand Canyon National Park believes that the presettlement model proposed by Northern Arizona University's forest ecosystem restoration proposal is justified. It is the best available interpretation of how the Southwestern ponderosa pine forest in the Park might have looked given the absence of livestock grazing and fire suppression. It mimics the clumpy nature of large old-growth trees with minimal episodic germination events surrounded by open, sunny meadows and grasslands with associated herbs and shrubs. The NAU model agrees with models proposed by other practitioners from other federal agencies and universities. Given that it is a model, additional research, which could be conducted in Grand Canyon and elsewhere, would help to refine the model. However, this experiment does not attempt to fully restore "presettlement" forest conditions. Rather, it concentrates on preserving old growth of all species.

5. Support commercial logging or support full project.

- *Public Comment:* Cost to taxpayers, let wood be used commercially.
  NPS Response: None of the 5-inch dbh wood to be cut on the research plots would be used commercially. The project was primarily funded by a special congressional appropriation in 1997 ($925,000) and other project accounts. This study would be focused on testing methods applicable to roadless areas, where wood removal is not economically feasible. Thinning would also be applied to trees below commercial size. Commercial use is therefore not practical or desirable for this experiment.
- *Public Comment:* Use helicopter logging.
  NPS Response: This experiment would not involve tree removal, so helicopters would not be needed. Only trees with a dbh of 5-inches or less would be cut and then dispersed on the site. Helicopters are not needed.
- *Public Comment:* Use mechanized whole tree logging or cable harvesting.
  NPS Response: This experiment would not involve tree removal, so mechanized whole tree logging or cable harvesting methods would not be needed.
- *Public Comment:* Sell trees to use income for future treatments.
  NPS Response: This experiment would not fell trees of commercial size. Cost of tree removal and mitigation would likely exceed the income that could be realized through sale. Therefore, no commercial use, sale to individuals or the public, salvage sales, or other income producing efforts would be used by this research proposal.
- *Public Comment:* Logging is good.
  NPS Response: While logging is applicable to other private, state, and federal lands, Grand Canyon National Park is required to consider other alternatives on park lands or in proposed wilderness. Our analysis indicates that logging would not be necessary to achieve project goals.
- *Public Comment:* Conduct research before Congress designates the North Rim research sites as wilderness.
  NPS Response: An area will not be excluded from a determination of wilderness suitability solely because established or proposed management practices require the use of tools, equipment, or structures, if those practices are necessary to meet the minimum requirements for the administration of the area as wilderness. For the purposes of applying these policies, the term, "wilderness" will include

the categories of suitable, study, proposed, recommended, and designated wilderness. The policies apply regardless of category. All management decisions affecting wilderness will further apply the concepts of "minimum requirements" for the administration of the area regardless of wilderness category. About 1,109,257 acres of Grand Canyon National Park's 1,218,375 acre area was recommended as wilderness in 1980. The area is not designated or authorized as potential wilderness, as both of these categories require establishment by an act of Congress.

- *Public Comment:* It is acceptable to give wood to Native American tribes, crafts people, or poor people.
  NPS Response: Both the Park Service and other Federal agencies have transferred wood for tribal use in the past. No wood would be removed from the research plots or utilized for any purposes other then on-site ecological benefits.

6. Support thinning of small trees.

- *Public Comment:* This is a worthy experiment.
  NPS Response: The research conducted by Northern Arizona University's Ecological Restoration Institute has been peer-reviewed and permitted by the NPS. Experience has shown that prescribed fire alone cannot effectively and safety achieve all resource goals.
- *Public Comment:* Support thinning of small or fewer trees.
  NPS Response: Under the revised work plan only trees less than 5-inches dbh would be cut. The only exception is that there may be specific trees determined hazardous for site prescribed burning. For example, a white fir tree with a dbh larger than 5-inches may be located under the drip line of an old growth ponderosa pine. It may need to be removed so that the ladder fuels do not cause the crown of the ponderosa pine to burn. Wood would be either piled or lopped and scattered for eventual burning by prescribed burns.
- *Public Comment:* Protect old growth trees.
  NPS Response: Protecting old growth ponderosa pine trees in the research study plots would be a high priority. Both live trees and snags within the minimal and intermediate restoration plots would be protected by the removal of duff from around the base. This protects the trees from lethal heating of the cambial cells at the root collar caused by smoldering duff layers, which can burn for up to 50 hours post-burn. Five-inch dbh trees and their associated aerial fuel ladders would be removed. At the request of the Park's fire management staff, duff would not be removed from around the base of old growth trees in the control and burn-only plots so that current management practices can be better evaluated.

7. Suggestions on research details.

- *Public Comment:* Research block size is too big or too small.
  NPS Response: Four 20-acre units comprise each experimental block. Each contains 20 plots on a 60-meter grid, approximately 1 plot per acre, for a total of 80 plots per experimental block or 240 plots for the three blocks (one of the blocks is on adjacent Forest Service lands). The measurements and plot design is adapted from the NPS Fire Monitoring system. Block size is comparable with other restoration blocks in Southwestern ponderosa pine forests.
- *Public Comment:* Project doesn't study insects, animals, and other plants.
  NPS Response: Other Northern Arizona University graduate studies are underway in Grand Canyon National Park. These include studies to document the effects of prescribed burning on mortality of presettlement ponderosa pines, describe the butterfly community structure in the ponderosa pine forest in remnant forest patches, model multi-century fire over landscape gradients, determine the understory reference conditions in the ponderosa pine forests, document the effects of restoration treatments on ponderosa pine understory, and determine the response of small mammal communities and Sin Nombre virus to ecological restoration of ponderosa pine.
- *Public Comment:* Project lacks fungal analysis.
  NPS Response: Northern Arizona University graduate studies are underway in Grand Canyon National Park studying the effect of restoration treatments on mycorrhizal fungal propagules in ponderosa pine forests. Other research is underway on this topic in other locations and could be applied to Grand Canyon NP. The Park would work to encourage additional research on the effect of forest restoration, prescribed fire, and fire suppression on fungi in the ponderosa pine and mixed-conifer stands. Research on other study sites, outside the Park, is also considering potential effects of restoration treatments on mycorrhizal soil fungus, reptiles, and other species.

- *Public Comment:* Need peer review of science projects.
  NPS Response: Park staff, fire research administrators, and various academicians reviewed the Northern Arizona University forest ecosystem restoration research proposal. Comments were compiled and factored into the revised study plan proposal. Upon completion of the proposed research and associated graduate studies, journal articles outlining various aspects of the forest restoration research would also be submitted to peer-reviewed journals for publication.
- *Public Comment:* Concern over less than credible science.
  NPS Response: Research funding was awarded to Northern Arizona University (NAU) after extensive peer review. NAU's Ecological Restoration Institute (ERI) is one of the nation's top schools in the field of forest restoration ecology. In 1999, ERI was awarded the Governor's Pride Award for Environmental Leadership. In 2000, the Arizona Board of Regents approved the ERI program. NAU's commitment to restoration was featured in the article "Ecological Restoration in Academia" by Brian Lavendel (Ecological Restoration 17(3):120-125, 1999). The students, staff, and professors of ERI have made numerous professional and academic presentations on restoration, published articles in peer-reviewed scientific journals, and conducted field and in-house tours.
- *Public Comment:* Doesn't emulate presettlement conditions.
  NPS Response: Ecological restoration is an attempt to reestablish the structure, function, and integrity of indigenous ecosystems, based upon a thorough understanding of the reference natural conditions. Presettlement conditions are those which existed prior to 1870, a date which is associated with the beginning of Euro-American settlement, heavy livestock grazing, and active fire suppression. Prior to 1870, frequent, low-intensity fires maintained presettlement forest conditions. Fires maintained an open forest ecosystem, a highly diverse understory of grasses and forbs**,** reduced tree population irruption following wet years, reduced forest floor accumulations of litter, maintained a high level of nutrient availability, and had a concomitant naturally functioning floral and faunal component. This experiment does not attempt to fully restore presettlement conditions. Rather it proposed to begin restoration by restoring fire as a natural process and removing some of the trees that survived as a result of fire exclusion.

Fire Topic

8. Prescribed fire.

- *Public Comment:* Restore the natural fire cycle.
  NPS Response: This research project would enable a better understanding of the natural fire cycle for Grand Canyon's forested ecosystems and the diverse biota that is dependent upon frequent fire. The research would assist land management agencies make more informed decisions upon the use of prescribed natural fire in the future. Research suggests that prior to Euro-American settlement, the natural fire cycle of Southwestern ponderosa pine was between two and twenty years. Prior to the fire suppression era which began in the early 1920s, the fire return interval cycle on the North Rim averaged four to ten years, and the South Rim is estimated to have averaged two to ten years. Three of the test treatments include prescribed fire. However, fire management experts have determined that the natural fire cycle cannot be safely restored to much of the ponderosa pine forest without reducing severe fuel load and invasive fires. Much of the forest could be destroyed by unnaturally severe wildfire if fire were reintroduced without reducing fuel loads first.
- *Public Comment:* Use controlled or prescribed burns only.
  NPS Response: Park fire management has used prescribed fire to clear accumulated fuels for the past 20 years. However, attempts to clear dense stands of small trees by fire alone can put the Park's resources at risk, both from wildfire and from less obvious heat damage to the bark and roots of older trees. Fire would be used to thin trees to the extent safely possible, but fire alone cannot safely treat dense stands of small diameter or "doghair" stands. Twenty years of research at the Chimney Spring site near Flagstaff, Arizona has demonstrated that fires that are sufficiently intense to clear doghair and pole stands will also destroy old growth, while cooler fires may not accomplish needed thinning. One of the four experimental plots is a "burn only" prescription allowing this method to be compared with the other restoration prescriptions and a control (or no burn) plot.
- *Public Comment:* Support prescribed fire.
  NPS Response: The Northern Arizona University forest restoration research project would use fire to thin trees to the maximum safe extent. Two years after burning, the effectiveness of the 5-inch dbh limit and other aspects of treatment would be assessed.
- *Public Comment:* Prescribed burning has air quality problems.

NPS Response: Smoke from the prescribed burning of the research projects would influence the Grand Canyon air quality and its associated air shed. Fire would only be applied following regulations of the Arizona Department of Environmental Quality (ADEQ). ADEQ burn approval is always obtained prior to any prescribed burning activity. Grand Canyon staff would monitor air quality and smoke emissions. A variety of "Best Management Practices" as described by ADEQ's 1996 Burn Rule (R18-2-1509) would be used to reduce smoke impacts associated with this prescribed burn. Burns would be conducted when smoke dispersion would be most favorable. Emissions would be managed to meet air quality regulations for particulate limits as prescribed for human health under the Federal Clean Air Act. Mechanical thinning conducted without fire would not accomplish study objectives related to reducing forest floor fuel loads, nutrient recycling, duff removal, and stimulation of fire adapted understory vegetation.

- *Public Comment:* Let catastrophic fires take place.
  NPS Response: Allowing catastrophic fires to destroy large expanses of the forested ecosystem and cultural landscape of Grand Canyon is in direct conflict with the 1916 Organic Act. This Act directs the NPS to regulate park use and promote enjoyment of parklands in a manner consistent with the conservation of the park's scenery, natural and historic objects, and wildlife. Catastrophic fire destroys habitat for all vegetation and wildlife, such as the northern goshawk, Mexican spotted owl, and Kaibab squirrel, soil, and cultural and recreational resources. Recovery from large-scale wildfire would take hundreds of years and place the human and resource values and benefits at risk. Given evidence about global clime change and the fragmentation of modern ecosystems, full recovery may not even occur.
- *Public Comment:* Project not integrated with past and future fire programs.
  NPS Response: NPS management staff reviewed and influenced study design and site selection. Prescribed burning of the research plots would be made in full cooperation and integration with the Grand Canyon Fire Management Plan (FMP). Every effort would be made to work within the Park's FMP through an adaptive management framework. Long-term monitoring of this project would be paramount to the research and future Park management decisions. This research would also provide information critically needed for future fire program planning.

Public Involvement and Compliance Topics

9. Public involvement.

- *Public Comment:* Extend the comment period or increase participation.
  NPS Response: The comment period on the draft Environmental Assessment was held between January 11 to February 23, 1999. An official extension was given from February 24 to March 25th. Comment analysis also included comments received between March 25 and August 29, 1999. Information on the forest restoration research has been available to the public by postings on the World Wide Web (see the Internet sites www.nps.gov/grca and www.thecanyon.com/nps/future). A workshop was held with interested environmental groups in March 1998 and public meetings were held on February 11, 1999 at Flagstaff and on February 12, 1999 at Kanab, Utah. Public meetings will also be held for this Environmental Assessment.
- *Public Comment:* The public needs to be educated about forest health.
  NPS Response: We recognize the continued need for public education about forest health. Since 1920, wildfires have become progressively larger, hotter, and more destructive to the forest, soil, and wildlife because there has been an increase in fuel loading due to the fire suppression activities. In 1996, following a regional drought in 1995-96, there were large forest fires near Flagstaff (Hochderffer Fire, 16,000 acres and the Horseshoe Fire, 8,650 acres) and on the North Kaibab Forest (Bridger Knoll Fire, 53,000 acres). In 2000, fires resulting from prescribed burns which turned into wildland fire in New Mexico (Cerro Grande Fire, ca. 45,000 acres and 235 homes destroyed) and the Park's North Rim and adjacent Kaibab National Forest (Outlet Fire, 13,548 acres) have brought the issue of forest health, prescribed burning, and wildland fire to the public's attention. Nationally, in 1999, the General Accounting Office reported to Congress that 39 million acres of national forest lands in the interior West were at a high risk of catastrophic wildfire. Regionally, efforts by the Coconino National Forest, the Flagstaff, Fire Department, the Grand Canyon Forest Foundation, and others have increased the local awareness of the need for fuel reduction plans. The NPS is working to increase public knowledge of forest health issues through publications, public meetings and seminars, and through cooperating with others in annual meetings.
- *Public Comment:* Make sure public is informed.
  NPS Response: Public information has been and would continue to be an important part of this

research project. General press releases and public service announcements would be prepared and distributed to local radio stations, newspapers, and web sites in advance of any prescribed burning activity or forest restoration treatments one to two months ahead of any activity. Specific press releases and public service announcements would be prepared and distributed immediately before and during the life of any prescribed fire or thinning treatments within the research area. A member of the Park's interpretive staff would facilitate information to the public at prominent viewpoints where prescribed fire activity is visible to the public. Site visits to the demonstration sites would be available to interested public, civic, and agency groups.

10. Environmental compliance.

- *Public Comment:* Do not disturb Native American graves.
  NPS Response: Archeological surveys were conducted prior to final site selection. Park archeologists have found no Native American graves within the research plots. There would be no restoration treatments or prescribed burning activity on culturally sensitive sites.
- *Public Comment:* Draft Environmental Assessment is inadequate.
  NPS Response: The draft Environmental Assessment has been revised and improved following public comment and internal review. Revised work plans were prepared (August 1999 and October 2000). An in-Park review team assisted by the Chief of Environmental Compliance has ensured the adequacy and completeness of this revised Environmental Assessment, which follows agency NEPA guidelines.
- *Public Comment:* This proposed project needs an environmental impact statement (EIS) prepared.
  NPS Response: An in-Park project review team recommended that an environmental impact statement (EIS) was not appropriate for this research proposal because it is not a major federal action that would have a significant impact on the environment. In addition, there would be minimal impact on cultural resources, threatened and endangered species, floodplains, or wetlands. Technically, neither an EA nor EIS would be required. However, Park management chose to complete an EA for this experiment to ensure resources would be protected, to document the decision process, and to involve the public. Prior to any application of the research or any future ecosystem based forest management policy, additional compliance would be needed, and that could lead to an EIS.
- *Public Comment:* National Park Service should have done a better job in this project.
  NPS Response: The staff of Grand Canyon National Park has made a concerted effort to obtain the best available science, peer review, and administration to this research project. We believe that the pubic review of the draft EA and the adaptive management process would culminate in the best available information on possible Park management decisions and options for restoration of the ponderosa pine forests on North and South Rims of the Park.
- *Public Comment:* No economic analysis was done.
  NPS Response: An economic analysis is not necessary for a small-scale research project. No wood would be sold for commercial profit. No economic impacts to surrounding communities are expected from this proposed experiment.
- *Public Comment:* NEPA should be done for site selection.
  NPS Response: The work plan and EA for this project considers site specific issues. Park staff and Northern Arizona University researchers jointly considered and evaluated alternative locations for the eight 20-acre research plots. The South Rim site was selected because (1) it could be paired with an adjacent Forest Service restoration research sites, (2) it was representative of the ponderosa pine dominated forest, and (3) the interested public could easily access it by vehicle. The North Rim site was selected because it (1) could be easily visited by the interested public, (2) was currently part of prescribed natural fire zone, where fire has not yet been reintroduced, (3) is in an area where wildfires are a severe risk and is immediately adjacent to the site of a severe wildfire (North West III) which was well documented by an Interagency group, (4) is in an ecological gradient, and (5) is representative of a ponderosa pine and mixed conifer forest. No other sites located on the North Rim had these characteristics. Larger landscape units surround both sites where additional fire history information could be collected. Both areas are under NPS management enabling long-term monitoring research and protection.

APPENDIX E
EXPERIMENTAL BLOCK TREE DATA
GRAND CANYON NATIONAL PARK

ALTERNATIVE "B"

TABLE 1. Full Restoration on the Grandview Experimental Block

Table 1A. Ponderosa Pine Forest Structure

D.B.H	EXISTING TREES/AC	EXISTING BA/AC*	REMOVED TREES/AC	REMOVED BA/AC*	RESIDUAL TREES/AC	RESIDUAL BA/AC*
1.0 – 4.9	57.1	3.23	57.1	3.23	0	0
5.0 – 8.9	63.7	16.85	63.7	16.85	0	0
9.0 – 11.9	20.2	11.80	14.2	7.54	6.1	4.2
12.0 – 15.9	7.6	7.49	0	0	4.6	7.49
16.0 – 19.9	5.1	8.42	0	0	5.1	8.4
20.0 – 23.9	3.5	9.38	0	0	3.5	9.38
24.0 – 27.9	4.0	14.72	0	0	4.0	14.72
28.0 – 31.9	0.5	2.54	0	0	0.5	2.54
32.0+	1.0	6.06	0	0	1.0	6.06
Totals:	162.7	80.49	135	27.62	24.8	52.79

Table 1B. Gambel Oak Forest Structure

D.B.H CLASS	EXISTING TREES/AC	EXISTING BA/AC	REMOVED TREES/AC	REMOVED BA/AC	RESIDUAL TREES/AC	RESIDUAL BA/AC
1.0 – 4.9	59.7	3.72	59.2	3.69	0.5	0.03
5.0 – 8.9	33.9	7.00	16.7	2.55	17.2	4.45
9.0 – 11.9	3.0	1.68	0	0	3.0	1.68
12.0 – 15.9	1.0	1.01	0	0	1.0	1.01
16.0 – 19.9	0.5	1.03	0	0	0.5	1.03
20.0 – 23.9	0.5	1.32	0	0	0.5	1.32
24.0 – 27.9	0.5	1.66	0	0	0.5	1.66
28.0 – 31.9	0	0	0	0	0	0
32.0+	0	0	0	0	0	0
Totals:	99.1	17.42	75.9	6.24	23.2	11.18

Table 1C. Utah Juniper Forest Structure

D.B.H CLASS	EXISTING TREES/AC	EXISTING BA/AC	REMOVED TREES/AC	REMOVED BA/AC	RESIDUAL TREES/AC	RESIDUAL BA/AC
1.0 – 4.9	1.0	0.02	1.0	0.02	0	0
5.0 – 8.9	1.0	0.36	1.0	0.36	0	0
9.0 – 11.9	0	0	0	0	0	0
12.0 – 15.9	0	0	0	0	0	0
16.0 – 19.9	0	0	0	0	0	0
20.0 – 23.9	0	0	0	0	0	0
24.0 – 27.9	0	0	0	0	0	0
28.0 – 31.9	0	0	0	0	0	0
32.0+	0	0	0	0	0	0
Totals:	2	0.38	2	0.38	0	0

- Throughout the appendix Basal Area is given in feet^2/acre.

Table 1D. Pinyon Pine Forest Structure

D.B.H CLASS	EXISTING TREES/AC	EXISTING BA/AC	REMOVED TREES/AC	REMOVED BA/AC	RESIDUAL TREES/AC	RESIDUAL BA/AC
1.0 – 4.9	1.0	0.02	1.0	0.02	0	0
5.0 – 8.9	0	0	0	0	0	0
9.0 – 11.9	0	0	0	0	0	0
12.0 – 15.9	0	0	0	0	0	0
16.0 – 19.9	0	0	0	0	0	0
20.0 – 23.9	0	0	0	0	0	0
24.0 – 27.9	0	0	0	0	0	0
28.0 – 31.9	0	0	0	0	0	0
32.0+	0	0	0	0	0	0
Totals:	1	0.02	1	0.02	0	0

TABLE 2. Minimal Thinning on the Grandview Experimental Block

Table 2A. Ponderosa Pine Forest Structure

D.B.H	EXISTING TREES/AC	EXISTING BA/AC	REMOVED TREES/AC	REMOVED BA/AC	RESIDUAL TREES/AC	RESIDUAL BA/AC
1.0 – 4.9	65.8	3.66	57.2	3.14	8.6	0.53
5.0 – 8.9	53.6	13.14	32.4	6.42	21.2	6.720
9.0 – 11.9	12.1	6.71	0	0	12.1	6.71
12.0 – 15.9	5.1	5.14	0	0	5.1	5.14
16.0 – 19.9	4.6	8.35	0	0	4.6	8.35
20.0 – 23.9	7.6	19.77	0	0	7.6	19.77
24.0 – 27.9	4.6	16.85	0	0	4.6	16.85
28.0 – 31.9	1.5	7.56	0	0	1.5	7.56
32.0+	0	0	0	0	0	0
Totals:	154.9	81.18	89.6	9.56	65.3	71.63

Table 2B. Gambel Oak Forest Structure

D.B.H CLASS	EXISTING TREES/AC	EXISTING BA/AC	REMOVED TREES/AC	REMOVED BA/AC	RESIDUAL TREES/AC	RESIDUAL BA/AC
1.0 – 4.9	193.2	13.43	157.3	10.71	35.9	2.72
5.0 – 8.9	35.4	7.17	0	0	35.4	7.17
9.0 – 11.9	4.6	2.74	0	0	4.6	2.74
12.0 – 15.9	1.5	1.54	0	0	1.5	1.54
16.0 – 19.9	0.5	0.84	0	0	0.5	0.84
20.0 – 23.9	0	0	0	0	0	0
24.0 – 27.9	0	0	0	0	0	0
28.0 – 31.9	0	0	0	0	0	0
32.0+	0	0	0	0	0	0
Totals:	235.2	25.72	157.3	10.71	77.9	15.01

Table 2C. Utah Juniper Forest Structure

D.B.H CLASS	EXISTING TREES/AC	EXISTING BA/AC	REMOVED TREES/AC	REMOVED BA/AC	RESIDUAL TREES/AC	RESIDUAL BA/AC
1.0 – 4.9	0.5	0.02	0.5	0.02	0	0
5.0 – 8.9	0	0	0	0	0	0
9.0 – 11.9	0	0	0	0	0	0
12.0 – 15.9	0	0	0	0	0	0
16.0 – 19.9	0	0	0	0	0	0
20.0 – 23.9	0	0	0	0	0	0
24.0 – 27.9	0	0	0	0	0	0
28.0 – 31.9	0	0	0	0	0	0
32.0+	0	0	0	0	0	0
Totals:	0.5	0.02	0.5	0.02	0	0

Table 2D. Pinyon Pine Forest Structure

D.B.H CLASS	EXISTING TREES/AC	EXISTING BA/AC	REMOVED TREES/AC	REMOVED BA/AC	RESIDUAL TREES/AC	RESIDUAL BA/AC
1.0 – 4.9	3.0	0.07	3.0	0.07	0	0
5.0 – 8.9	0	0	0	0	0	0
9.0 – 11.9	0	0	0	0	0	0
12.0 – 15.9	0	0	0	0	0	0
16.0 – 19.9	0	0	0	0	0	0
20.0 – 23.9	0	0	0	0	0	0
24.0 – 27.9	0	0	0	0	0	0
28.0 – 31.9	0	0	0	0	0	0
32.0+	0	0	0	0	0	0
Totals:	3	0.07	3	0.07	0	0

TABLE 3. Full Restoration on the North Rim Experimental Block

Table 3A. Ponderosa Pine Forest Structure

D.B.H	EXISTING TREES/AC	EXISTING BA/AC	REMOVED TREES/AC	REMOVED BA/AC	RESIDUAL TREES/AC	RESIDUAL BA/AC
1.0 – 4.9	19.2	1.25	3.5	0.04	15.7	1.21
5.0 – 8.9	12.6	3.19	0	0	12.6	3.19
9.0 – 11.9	2.5	1.67	0	0	2.5	1.67
12.0 – 15.9	3.0	3.15	0	0	3.0	3.15
16.0 – 19.9	4.6	8.08	0	0	4.6	8.08
20.0 – 23.9	4.0	10.27	0	0	4.0	10.27
24.0 – 27.9	5.6	20.45	0	0	5.6	20.45
28.0 – 31.9	4.0	18.21	0	0	4.0	18.21
32.0+	1.0	7.24	0	0	1.0	7.24
Totals:	56.5	73.51	3.5	0.04	53	73.47

Table 3B. White fir Forest Structure

D.B.H CLASS	EXISTING TREES/AC	EXISTING BA/AC	REMOVED TREES/AC	REMOVED BA/AC	RESIDUAL TREES/AC	RESIDUAL BA/AC
1.0 – 4.9	126.5	5.06	126.5	5.06	0	0
5.0 – 8.9	38.9	9.81	1.0	0.28	37.9	9.53
9.0 – 11.9	12.1	7.11	0	0	12.4	7.11
12.0 – 15.9	12.6	13.05	0	0	12.6	13.05
16.0 – 19.9	8.6	15.24	0	0	8.6	15.24
20.0 – 23.9	5.6	13.93	0	0	5.6	13.93
24.0 – 27.9	3.5	13.22	0	0	3.5	13.22
28.0 – 31.9	2.0	10.25	0	0	2.0	10.25
32.0+	1.0	6.5	0	0	1.0	6.5
Totals:	210.8	94.17	127.5	5.34	83.6	88.83

Table 3C. Aspen Forest Structure

D.B.H CLASS	EXISTING TREES/AC	EXISTING BA/AC	REMOVED TREES/AC	REMOVED BA/AC	RESIDUAL TREES/AC	RESIDUAL BA/AC
1.0 – 4.9	19.2	0.55	0	0	19.22	0.55
5.0 – 8.9	19.2	5.63	0	0	19.2	5.63
9.0 – 11.9	10.6	6.28	0	0	10.6	6.28
12.0 – 15.9	5.6	5.29	0	0	5.6	5.29
16.0 – 19.9	0.5	0.84	0	0	0.5	0.84
20.0 – 23.9	0	0	0	0	0	0
24.0 – 27.9	0	0	0	0	0	0
28.0 – 31.9	0	0	0	0	0	0
32.0+	0	0	0	0	0	0
Totals:	55.1	18.59	0	0	55.12	18.59

Table 3D. Douglas-fir Forest Structure

D.B.H CLASS	EXISTING TREES/AC	EXISTING BA/AC	REMOVED TREES/AC	REMOVED BA/AC	RESIDUAL TREES/AC	RESIDUAL BA/AC
1.0 – 4.9	33.9	1.22	33.9	1.22	0	0
5.0 – 8.9	9.1	2.33	9.1	2.33	0	0
9.0 – 11.9	3.5	2.19	3.5	2.19	0	0
12.0 – 15.9	2.0	2.16	1.5	1.51	0.5	0.65
16.0 – 19.9	2.5	4.21	0.5	0.82	2.0	3.39
20.0 – 23.9	0.5	1.23	0	0	0.5	1.23
24.0 – 27.9	1.0	3.63	0	0	1.0	3.63
28.0 – 31.9	0	0	0	0	0	0
32.0+	0	0	0	0	0	0
Totals:	52.5	16.97	48.5	8.07	4	8.9

TABLE 4. Minimal Thinning on the North Rim Experimental Block

Table 4A. Ponderosa Pine Forest Structure

D.B.H	EXISTING TREES/AC	EXISTING BA/AC	REMOVED TREES/AC	REMOVED BA/AC	RESIDUAL TREES/AC	RESIDUAL BA/AC
1.0 – 4.9	20.7	0.92	7.1	0.09	13.7	0.83
5.0 – 8.9	19.7	5.05	0	0	19.7	5.05
9.0 – 11.9	6.1	3.80	0	0	6.1	3.80
12.0 – 15.9	9.1	9.25	0	0	9.1	9.25
16.0 – 19.9	4.0	7.00	0	0	4.0	7.00
20.0 – 23.9	5.6	15.56	0	0	5.6	15.56
24.0 – 27.9	5.1	18.63	0	0	5.1	18.63
28.0 – 31.9	7.6	36.31	0	0	7.6	36.31
32.0+	2.0	12.76	0	0	2.0	12.76
Totals:	79.9	109.28	7.1	0.09	72.9	109.19

Table 4B. White fir Forest Structure

D.B.H CLASS	EXISTING TREES/AC	EXISTING BA/AC	REMOVED TREES/AC	REMOVED BA/AC	RESIDUAL TREES/AC	RESIDUAL BA/AC
1.0 – 4.9	135.6	7.82	123.4	4.33	12.1	0.49
5.0 – 8.9	29.8	7.51	4.0	0.60	25.8	6.91
9.0 – 11.9	14.7	8.42	0.5	0.31	14.2	8.11
12.0 – 15.9	10.6	11.44	0	0	10.6	11.44
16.0 – 19.9	5.6	9.35	0	0	5.6	9.35
20.0 – 23.9	3.5	9.05	0	0	3.5	9.05
24.0 – 27.9	2.0	7.60	0	0	2.0	7.60
28.0 – 31.9	1.0	5.24	0	0	1.0	5.24
32.0+	0	0	0	0	0	0
Totals:	202.8	66.43	127.9	5.24	74.8	58.19

Table 4C. Aspen Forest Structure

D.B.H CLASS	EXISTING TREES/AC	EXISTING BA/AC	REMOVED TREES/AC	REMOVED BA/AC	RESIDUAL TREES/AC	RESIDUAL BA/AC
1.0 – 4.9	18.2	0.26	0	0	18.2	0.26
5.0 – 8.9	5.6	1.75	0	0	5.6	1.75
9.0 – 11.9	5.6	3.18	0	0	5.6	3.18
12.0 – 15.9	3.0	2.93	0	0	3.0	2.93
16.0 – 19.9	1.0	1.71	0	0	1.0	1.71
20.0 – 23.9	0	0	0	0	0	0
24.0 – 27.9	0	0	0	0	0	0
28.0 – 31.9	0	0	0	0	0	0
32.0+	0	0	0	0	0	0
Totals:	33.4	9.83	0	0	33.4	9.83

Table 4D. Douglas-fir Forest Structure

D.B.H CLASS	EXISTING TREES/AC	EXISTING BA/AC	REMOVED TREES/AC	REMOVED BA/AC	RESIDUAL TREES/AC	RESIDUAL BA/AC
1.0 – 4.9	14.7	0.67	13.7	0.65	1.0	0.02
5.0 – 8.9	7.1	1.70	5.6	1.34	1.5	0.35
9.0 – 11.9	2.5	1.44	0.5	0.24	2.0	1.20
12.0 – 15.9	0.5	0.42	0	0	0.5	0.42
16.0 – 19.9	0.5	0.71	0	0	0.5	0.71
20.0 – 23.9	0.5	1.34	0	0	0.5	1.34
24.0 – 27.9	0.5	1.86	0	0	0.5	1.86
28.0 – 31.9	0.5	2.61	0	0	0.5	2.61
32.0+	0	0	0	0	0	0
Totals:	26.8	10.75	19.8	2.23	7	8.51

TABLE 5. Intermediate Treatment on the Grandview Experimental Block

Table 5A. Ponderosa Pine Forest Structure

D.B.H	EXISTING TREES/AC	EXISTING BA/AC	REMOVED TREES/AC	REMOVED BA/AC	RESIDUAL TREES/AC	RESIDUAL BA/AC
1.0 – 4.9	57.1	3.23	57.1	3.23	0	0
5.0 – 8.9	63.7	16.85	0	0	63.7	16.85
9.0 – 11.9	20.2	11.80	0	0	20.2	11.80
12.0 – 15.9	7.6	7.49	0	0	4.6	7.49
16.0 – 19.9	5.1	8.42	0	0	5.1	8.4
20.0 – 23.9	3.5	9.38	0	0	3.5	9.38
24.0 – 27.9	4.0	14.72	0	0	4.0	14.72
28.0 – 31.9	0.5	2.54	0	0	0.5	2.54
32.0+	1.0	6.06	0	0	1.0	6.06
Totals:	162.7	80.49	57.1	3.23	105.6	77.26

Table 5B. Gambel Oak Forest Structure

D.B.H CLASS	EXISTING TREES/AC	EXISTING BA/AC	REMOVED TREES/AC	REMOVED BA/AC	RESIDUAL TREES/AC	RESIDUAL BA/AC
1.0 – 4.9	59.7	3.72	59.7	3.72	0	0
5.0 – 8.9	33.9	7.00	0	0	33.9	7.00
9.0 – 11.9	3.0	1.68	0	0	3.0	1.68
12.0 – 15.9	1.0	1.01	0	0	1.0	1.01
16.0 – 19.9	0.5	1.03	0	0	0.5	1.03
20.0 – 23.9	0.5	1.32	0	0	0.5	1.32
24.0 – 27.9	0.5	1.66	0	0	0.5	1.66
28.0 – 31.9	0	0	0	0	0	0
32.0+	0	0	0	0	0	0
Totals:	99.1	17.42	59.7	3.72	39.4	13.7

Table 5C. Utah Juniper Forest Structure

D.B.H CLASS	EXISTING TREES/AC	EXISTING BA/AC	REMOVED TREES/AC	REMOVED BA/AC	RESIDUAL TREES/AC	RESIDUAL BA/AC
1.0 – 4.9	1.0	0.02	1.0	0.02	0	0
5.0 – 8.9	1.0	0.36	0	0	1.0	0.36
9.0 – 11.9	0	0	0	0	0	0
12.0 – 15.9	0	0	0	0	0	0
16.0 – 19.9	0	0	0	0	0	0
20.0 – 23.9	0	0	0	0	0	0
24.0 – 27.9	0	0	0	0	0	0
28.0 – 31.9	0	0	0	0	0	0
32.0+	0	0	0	0	0	0
Totals:	2.0	0.38	1.0	0.02	1.0	0.36

Table 5D. Pinyon Pine Forest Structure

D.B.H CLASS	EXISTING TREES/AC	EXISTING BA/AC	REMOVED TREES/AC	REMOVED BA/AC	RESIDUAL TREES/AC	RESIDUAL BA/AC
1.0 – 4.9	1.0	0.02	1.0	0.02	0	0
5.0 – 8.9	0	0	0	0	0	0
9.0 – 11.9	0	0	0	0	0	0
12.0 – 15.9	0	0	0	0	0	0
16.0 – 19.9	0	0	0	0	0	0
20.0 – 23.9	0	0	0	0	0	0
24.0 – 27.9	0	0	0	0	0	0
28.0 – 31.9	0	0	0	0	0	0
32.0+	0	0	0	0	0	0
Totals:	1	0.02	1	0.02	0	0

TABLE 6. Minimal Treatment on the Grandview Experimental Block

Table 6A. Ponderosa Pine Forest Structure

D.B.H	EXISTING TREES/AC	EXISTING BA/AC	REMOVED TREES/AC	REMOVED BA/AC	RESIDUAL TREES/AC	RESIDUAL BA/AC
1.0 – 4.9	65.8	3.66	57.2	3.14	8.6	0.53
5.0 – 8.9	53.6	13.14	0	0	53.6	13.14
9.0 – 11.9	12.1	6.71	0	0	12.1	6.71
12.0 – 15.9	5.1	5.14	0	0	5.1	5.14
16.0 – 19.9	4.6	8.35	0	0	4.6	8.35
20.0 – 23.9	7.6	19.77	0	0	7.6	19.77
24.0 – 27.9	4.6	16.85	0	0	4.6	16.85
28.0 – 31.9	1.5	7.56	0	0	1.5	7.56
32.0+	0	0	0	0	0	0
Totals:	154.9	81.18	57.2	3.14	97.7	78.04

Table 6B. Gambel Oak Forest Structure

D.B.H CLASS	EXISTING TREES/AC	EXISTING BA/AC	REMOVED TREES/AC	REMOVED BA/AC	RESIDUAL TREES/AC	RESIDUAL BA/AC
1.0 – 4.9	193.2	13.43	157.3	10.71	35.9	2.72
5.0 – 8.9	35.4	7.17	0	0	35.4	7.17
9.0 – 11.9	4.6	2.74	0	0	4.6	2.74
12.0 – 15.9	1.5	1.54	0	0	1.5	1.54
16.0 – 19.9	0.5	0.84	0	0	0.5	0.84
20.0 – 23.9	0	0	0	0	0	0
24.0 – 27.9	0	0	0	0	0	0
28.0 – 31.9	0	0	0	0	0	0
32.0+	0	0	0	0	0	0
Totals:	235.2	25.72	157.3	10.71	77.9	15.01

Table 6C. Utah Juniper Forest Structure

D.B.H CLASS	EXISTING TREES/AC	EXISTING BA/AC	REMOVED TREES/AC	REMOVED BA/AC	RESIDUAL TREES/AC	RESIDUAL BA/AC
1.0 – 4.9	0.5	0.02	0.5	0.02	0	0
5.0 – 8.9	0	0	0	0	0	0
9.0 – 11.9	0	0	0	0	0	0
12.0 – 15.9	0	0	0	0	0	0
16.0 – 19.9	0	0	0	0	0	0
20.0 – 23.9	0	0	0	0	0	0
24.0 – 27.9	0	0	0	0	0	0
28.0 – 31.9	0	0	0	0	0	0
32.0+	0	0	0	0	0	0
Totals:	0.5	0.02	0.5	0.02	0	0

Table 6D. Pinyon Pine Forest Structure

D.B.H CLASS	EXISTING TREES/AC	EXISTING BA/AC	REMOVED TREES/AC	REMOVED BA/AC	RESIDUAL TREES/AC	RESIDUAL BA/AC
1.0 – 4.9	3.0	0.07	3.0	0.07	0	0
5.0 – 8.9	0	0	0	0	0	0
9.0 – 11.9	0	0	0	0	0	0
12.0 – 15.9	0	0	0	0	0	0
16.0 – 19.9	0	0	0	0	0	0
20.0 – 23.9	0	0	0	0	0	0
24.0 – 27.9	0	0	0	0	0	0
28.0 – 31.9	0	0	0	0	0	0
32.0+	0	0	0	0	0	0
Totals:	3	0.07	3	0.07	0	0

TABLE 7. Intermediate Treatment on the North Rim Experimental Block

Table 7A. Ponderosa Pine Forest Structure

D.B.H	EXISTING TREES/AC	EXISTING BA/AC	REMOVED TREES/AC	REMOVED BA/AC	RESIDUAL TREES/AC	RESIDUAL BA/AC
1.0 – 4.9	19.2	1.25	3.5	0.04	15.7	1.21
5.0 – 8.9	12.6	3.19	0	0	12.6	3.19
9.0 – 11.9	2.5	1.67	0	0	2.5	1.67
12.0 – 15.9	3.0	3.15	0	0	3.0	3.15
16.0 – 19.9	4.6	8.08	0	0	4.6	8.08
20.0 – 23.9	4.0	10.27	0	0	4.0	10.27
24.0 – 27.9	5.6	20.45	0	0	5.6	20.45
28.0 – 31.9	4.0	18.21	0	0	4.0	18.21
32.0+	1.0	7.24	0	0	1.0	7.24
Totals:	56.5	73.51	3.5	0.04	53	73.47

Table 7B. White fir Forest Structure

D.B.H CLASS	EXISTING TREES/AC	EXISTING BA/AC	REMOVED TREES/AC	REMOVED BA/AC	RESIDUAL TREES/AC	RESIDUAL BA/AC
1.0 – 4.9	126.5	5.06	126.5	5.06	0	0
5.0 – 8.9	38.9	9.81	0	0	38.9	9.81
9.0 – 11.9	12.1	7.11	0	0	12.1	7.11
12.0 – 15.9	12.6	13.05	0	0	12.6	13.05
16.0 – 19.9	8.6	15.24	0	0	8.6	15.24
20.0 – 23.9	5.6	13.93	0	0	5.6	13.93
24.0 – 27.9	3.5	13.22	0	0	3.5	13.22
28.0 – 31.9	2.0	10.25	0	0	2.0	10.25
32.0+	1.0	6.5	0	0	1.0	6.5
Totals:	210.8	94.17	126.5	5.06	84.3	89.11

Table 7C. Aspen Forest Structure

D.B.H CLASS	EXISTING TREES/AC	EXISTING BA/AC	REMOVED TREES/AC	REMOVED BA/AC	RESIDUAL TREES/AC	RESIDUAL BA/AC
1.0 – 4.9	19.2	0.55	0	0	19.2	0.55
5.0 – 8.9	19.2	5.63	0	0	19.2	5.63
9.0 – 11.9	10.6	6.28	0	0	10.6	6.28
12.0 – 15.9	5.6	5.29	0	0	5.6	5.29
16.0 – 19.9	0.5	0.84	0	0	0.5	0.84
20.0 – 23.9	0	0	0	0	0	0
24.0 – 27.9	0	0	0	0	0	0
28.0 – 31.9	0	0	0	0	0	0
32.0+	0	0	0	0	0	0
Totals:	55.1	18.59	0	0	55.1	18.59

Table 7D. Douglas-fir Forest Structure

D.B.H CLASS	EXISTING TREES/AC	EXISTING BA/AC	REMOVED TREES/AC	REMOVED BA/AC	RESIDUAL TREES/AC	RESIDUAL BA/AC
1.0 – 4.9	33.9	1.22	33.9	1.22	0	0
5.0 – 8.9	9.1	2.33	0	0	9.1	2.33
9.0 – 11.9	3.5	2.19	0	0	3.5	2.19
12.0 – 15.9	2.0	2.16	0	0	2.0	2.16
16.0 – 19.9	2.5	4.21	0	0	2.5	4.21
20.0 – 23.9	0.5	1.23	0	0	0.5	1.23
24.0 – 27.9	1.0	3.63	0	0	1.0	3.63
28.0 – 31.9	0	0	0	0	0	0
32.0+	0	0	0	0	0	0
Totals:	52.5	16.97	33.9	1.22	18.6	15.75

TABLE 8. Minimal Treatment on the North Rim Experimental Block

Table 8A. Ponderosa Pine Forest Structure

D.B.H	EXISTING TREES/AC	EXISTING BA/AC	REMOVED TREES/AC	REMOVED BA/AC	RESIDUAL TREES/AC	RESIDUAL BA/AC
1.0 – 4.9	20.7	0.92	7.1	0.09	13.7	0.83
5.0 – 8.9	19.7	5.05	0	0	19.7	5.05
9.0 – 11.9	6.1	3.80	0	0	6.1	3.80
12.0 – 15.9	9.1	9.25	0	0	9.1	9.25
16.0 – 19.9	4.0	7.00	0	0	4.0	7.00
20.0 – 23.9	5.6	15.56	0	0	5.6	15.56
24.0 – 27.9	5.1	18.63	0	0	5.1	18.63
28.0 – 31.9	7.6	36.31	0	0	7.6	36.31
32.0+	2.0	12.76	0	0	2.0	12.76
Totals:	79.9	109.28	7.1	0.09	72.9	109.19

Table 8B. White fir Forest Structure

D.B.H CLASS	EXISTING TREES/AC	EXISTING BA/AC	REMOVED TREES/AC	REMOVED BA/AC	RESIDUAL TREES/AC	RESIDUAL BA/AC
1.0 – 4.9	135.6	7.82	123.4	4.33	12.1	0.49
5.0 – 8.9	29.8	7.51	0	0	29.8	7.51
9.0 – 11.9	14.7	8.42	0	0	14.7	8.42
12.0 – 15.9	10.6	11.44	0	0	10.6	11.44
16.0 – 19.9	5.6	9.35	0	0	5.6	9.35
20.0 – 23.9	3.5	9.05	0	0	3.5	9.05
24.0 – 27.9	2.0	7.60	0	0	2.0	7.60
28.0 – 31.9	1.0	5.24	0	0	1.0	5.24
32.0+	0	0	0	0	0	0
Totals:	202.8	66.43	123.4	4.33	79.4	62.1

Table 8C. Aspen Forest Structure

D.B.H CLASS	EXISTING TREES/AC	EXISTING BA/AC	REMOVED TREES/AC	REMOVED BA/AC	RESIDUAL TREES/AC	RESIDUAL BA/AC
1.0 – 4.9	18.2	0.26	0	0	18.2	0.26
5.0 – 8.9	5.6	1.75	0	0	5.6	1.75
9.0 – 11.9	5.6	3.18	0	0	5.6	3.18
12.0 – 15.9	3.0	2.93	0	0	3.0	2.93
16.0 – 19.9	1.0	1.71	0	0	1.0	1.71
20.0 – 23.9	0	0	0	0	0	0
24.0 – 27.9	0	0	0	0	0	0
28.0 – 31.9	0	0	0	0	0	0
32.0+	0	0	0	0	0	0
Totals:	33.4	9.83	0	0	33.4	9.83

Table 8D. Douglas-fir Forest Structure

D.B.H CLASS	EXISTING TREES/AC	EXISTING BA/AC	REMOVED TREES/AC	REMOVED BA/AC	RESIDUAL TREES/AC	RESIDUAL BA/AC
1.0 – 4.9	14.7	0.67	13.7	0.65	1.0	0.02
5.0 – 8.9	7.1	1.70	0	0	7.1	1.70
9.0 – 11.9	2.5	1.44	0	0	2.5	1.44
12.0 – 15.9	0.5	0.42	0	0	0.5	0.42
16.0 – 19.9	0.5	0.71	0	0	0.5	0.71
20.0 – 23.9	0.5	1.34	0	0	0.5	1.34
24.0 – 27.9	0.5	1.86	0	0	0.5	1.86
28.0 – 31.9	0.5	2.61	0	0	0.5	2.61
32.0+	0	0	0	0	0	0
Totals:	26.8	10.75	13.7	0.65	13.1	10.1

APPENDIX F. Comparison of treatments in the three Wildfire Hazard Reduction Research alternatives.

		ALTERNATIVE "A"	ALTERNATIVE "B"	ALTERNATIVE "C" – PREFERRED ACTION
CONTROL	methods	Not tested under this alternative.	Clear fireline around control unit and experimental block with power tools on North Rim at Grandview. See EA §II.B.4, page 13.	Clear fireline around control unit and experimental block with hand tools on North Rim and power tools at Grandview. See EA §II.C.4, page 17.
	activities	Fire management (prescribed fire, suppression) according to GRCA Fire Management Plan 1992 or revision	No thinning No burning Fire exclusion (firelines to prevent wild and prescribed fires)	No thinning No burning Fire exclusion (firelines to prevent wild and prescribed fires)
	Thinnin g	None	None	None
BURN-ONLY	methods	Not tested under this alternative.	See EA §II.B.3, page 13.	See EA §II.C.3, page 17.
	activities	Fire management (prescribed fire, suppression) according to GRCA Fire Management Plan 1992 or revision	Prescribed fire according to GRCA Fire Management Plan 1992 or revision	Prescribed fire according to GRCA Fire Management Plan 1992 or revision
	thinning	None	None	None
MINIMAL THINNING/ MINIMAL TREATMENT	methods	Not tested under this alternative.	Mark "save" trees with flagging and paint spot at ground level Thinning via chainsaws Trim stumps close to ground Skid logs with horse teams Rake duff from old trees and snags before burning Cut wood <6" diameter into 2-4' lengths; burn slash on site Remove logs with small trucks on open public roads See EA §II.B.2, pages 11-13.	Mark "save" trees ≤5" dbh with flagging and paint spot at ground level Thinning via chainsaws at Grandview and hand tools on North Rim Trim stumps close to ground No skidding or log removal Rake duff from old trees and snags before burning Cut wood into 2-4' lengths; burn slash on site Transport work crews w/ small trucks on open public roads See revised Work Plan pages 30-32, EA §II.C.2, pages 15-17.
	activities	Fire management (prescribed fire, suppression) according to GRCA Fire Management Plan 1992 or revision	Thin trees < 12" dbh around target trees Thinning via chainsaws Prescribed burning following thinning Wood transferred to BIA Raking around target trees	Thin trees < 5" dbh around target trees Thinning via chainsaws at Grandview and hand tools on North Rim Prescribed burning following thinning No wood removed from experimental blocks Raking around target trees
	thinning	None	7244 trees 1-4.9" 840 trees 5-8.9" 20 trees 9-11.9"	7244 trees 1-4.9"

		ALTERNATIVE "A"	ALTERNATIVE "B"	ALTERNATIVE "C" – PREFERRED ACTION
INTERMEDIATE TREATMENT	methods	Not tested under this alternative.	Not tested under this alternative.	Same as described for Minimal Treatment (above) See EA §II.C.1 & 2, pages 14-16.
	activities	Fire management (prescribed fire, suppression) according to GRCA Fire Management Plan 1992 or revision	Not tested under this alternative.	Thin most trees <5" dbh in treatment plot (except designated replacement trees) Thinning via chainsaws at Grandview and hand tools on North Rim Prescribed burning following thinning No wood removed from experimental blocks Raking around target trees
	thinning	None	Not tested under this alternative.	5654 trees 1-4.9"*
FULL RESTORATION	methods	Not tested under this alternative.	Same as described for Minimal Thinning (above) See EA §II.B.1 & 2, pages 9-11.	Not tested under this alternative.
	activities	Fire management (prescribed fire, suppression) according to GRCA Fire Management Plan 1992 or revision	Thin trees 1-19.9" dbh in treatment plot (except designated replacement trees) Thinning via chainsaws Prescribed burning following thinning Wood transferred to BIA Raking around target trees	Not tested under this alternative.
	thinning	None	5654 trees 1-4.9"* 1822 trees 5-8.9" 354 trees 9-11.0" 30 trees 12-15.9" (10 trees 16-19.9" – deleted when Dec. 1999 Work Plan and draft EA were developed)	Not tested under this alternative.

* Fewer small trees (size class 1-4.9" dbh) would be thinned in intermediate treatment or full restoration compared to minimal because of the randomized plot design.

APPENDIX G
SUMMARY OF 13 REGIONAL FOREST RESTORATION PROJECTS

Below is a summary of thirteen forest restoration projects within the ponderosa pine ecosystem in Northern Arizona. The projects are listed alphabetically by landowner and management unit.

1. Title: Navajo Army Depot
Landowner: Army National Guard.
Who: Northern Arizona University, College of Ecosystem Science and Management in cooperation with Army National Guard. Contact: Doc Smith, Ecological Research Institute, 523-7502.
What: In 1996, NAU began a study of 1,100 acres at Camp Navajo to study ponderosa pine reference conditions prior to European settlement. This led to a desire to apply ecosystem restoration prescriptions on this site. An invitation for treatment bids was made, but no bidders came forward. The Army has been reluctant to proceed until there is assurance that there will be payment for the wood to be removed by the restoration prescription. It is estimated that this would be about $50 per acre paid to the Army National Guard by the salvage contractor.
When: The project began in 1996, but is now on hold. No action has been taken.
Where: Camp Navajo, approximately 12 miles west of Flagstaff, south side of Interstate 40, near Bellemont.
How: Mechanical thinning by salvage contractor.

2. Mount Trumbull Forest Restoration
Landowner: Bureau of Land Management.
Who: Northern Arizona University, Ecological Restoration Institute, in cooperation with the Bureau of Land Management. Contact: W. Wallace Covington, Ecological Restoration Institute, 523-7187.
What: A research project with 5 pairs of treated and untreated 20-acre patches to test restoration effects on ponderosa pine (such as thinning of post-settlement trees, conserving pre-settlement trees greater than 125 years old, treating forest floor fuels, and reintroducing prescribed fire). Additional studies include the effect of restoration on passerine birds, small mammals, and insects. Restoration treatments have cost about $400 to $500 per acre, with reseeding costing up to $1,500 per acre.
When: 1995 to present
Where: Mount Trumbull Resource Conservation Area on the Arizona Strip, northwestern Arizona (northwest of Tuweep area and the Park boundary).
How: Mechanical thinning and prescribed burning.

3. Flagstaff Area Wildfire Risk Assessment
Landowner: City of Flagstaff, State of Arizona, and private landowners.
Who: Flagstaff Fire Department, Arizona State Land Department, Grand Canyon Forest Foundation, and Grand Canyon Forest Partnership. Contact: Paul Summerfelt, Flagstaff Fire Department, Fire Management Officer, 779-7688.
What: This project is essentially the same as the Fort Valley Ecosystem Restoration Project. However, as the sites are not on Federal lands, they are not under the same NEPA guidelines. Environmental groups have not contested this project in the ponderosa pine ecosystem as work is on state, city, and private lands. At this date, the project has included 13 fuel reduction projects in the Flagstaff/urban interface: A-1 Mountain, Equestrian Estates, Pumphouse Wash, Arboretum, Lake Mary, Skunk, Mars Hill, Sinagua High School, Mary's Café, Airport, various city lots, and Munds Park areas.
Where: 13 sites surrounding Flagstaff, Arizona.
How: Treatments (hand harvesting, cut-to-length harvesting, and whole-tree mechanized harvesting), prescribed fire, and thinning to decrease catastrophic fire risk. The Flagstaff Fire Dept. provides at no charge, professional assistance, including general advice, plan preparation, tree marking, project oversight, and broadcast and pile burns. Private vendors or property owners conduct the actual tree thinning.

4. Grand Canyon Forest Ecosystem Restoration
Landowner: National Park Service.
Who: Northern Arizona University in cooperation with Grand Canyon National Park. Contact: Pete Fulé, Ecological Research Institute, 523-1463.

What: This $925,000 research project proposes to research the current and historical forest conditions, research fire history, and develop, test and evaluate alternative forest management practices for ponderosa pine and mixed-conifer ecosystems.
When: A special congressional appropriation in 1997 began this project with a proposed two-year project from January 1998 to December 1999. A draft work plan and EA were released January 1999. A revised work plan was prepared October 2000.
Where: Two sites: (1) a North Rim site on Swamp Ridge with fire history data collected from Powell Plateau and Rainbow Ridge and (2) a South Rim site near the Grandview entrance with fire history data collected from the Grandview area.
How: Four research units in two sites to be tested using minimal thinning prescription, a modified thinning prescription, control burning, and no action. A third research site is located on the Tusayan Ranger District in the Grandview area (see Project No. 12).

5. Title: Sinclair Wash Forest Ecosystem Restoration
Landowner: State of Arizona.
Who: Northern Arizona University's College of Ecosystem Science and Management, Flagstaff Fire Department, and Flagstaff Parks and Recreation. Contact: Doc Smith, Ecological Research Institute, 523-7502.
What: A small demonstration plot in a second growth, ponderosa pine plot, approximately 3 acre in size, with an additional 3 acre plot used for a control to show forest restoration techniques. Additional future burns may be applied.
When: August 1998 to present.
Where: On Northern Arizona University's south campus along Sinclair Wash, northwest corner of McConnell Drive and San Francisco Street, Flagstaff.
How: Mechanical thinning and controlled burning.

6. Title: Blue Ridge Demonstration Project
Landowner: U.S. Forest Service.
Who: Apache-Sitgreaves National Forest and the Natural Resources Working Group (includes federal, tribal, state, and county and local government representatives as well as representatives of the environmental, ranching, and business communities, state universities, and interested public). Contact: Lawrence D. Garrett and Edward Collins at M3research@aol.com, or 520-567-4591.
What: 17,000 acre Blue Ridge Analysis Area, with three, 2,000 acre treatments (for a total of approximately 6,000 acres), with an adjacent control area to monitor resource change. An estimate of working costs for restoration in this ponderosa pine habitat is in-progress and is not available.
When: In-progress.
Where: Apache-Sitgreaves National Forest in Blue Ridge Analysis Area.
How: Thinning, wildlife habitat improvements, prescribed fire, etc. Initial treatments protect old growth, improve wildlife habitat and reduce fire risk by removal of small diameter trees. Also pre-settlement tree numbers and locations are mapped.

7. Title: Fort Valley Ecosystem Restoration Project
Landowners: U.S. Forest Service.
Who: Peaks Ranger District, Coconino National Forest in cooperation with the Flagstaff Fire Department and Grand Canyon Forest Partnership. The partnership includes 17 organizations, agencies, and groups including Grand Canyon Trust, Arizona State Land Department, Northern Arizona University's College of Ecosystem Science and Management, and the Ponderosa Fire Advisory Council. Contacts: Tammy Randal-Parker, Peaks Ranger District, 527-8254, and Taylor McKinnon, Grand Canyon Trust, 774-7488.
What: A 100,000 acre unit of ponderosa pine of which 1,700 acres is proposed to be treated by mechanical means to thin the congested forest. It also proposes to close roads and use prescribed burns. The Fort Valley Project is also called the Fort Valley Urban/Wildland Project.
When: March 1998 to present.
Where: Forest Service lands north and west of Flagstaff, AZ. The site is bounded on the east by the Schultz Pass Road, on the north by Freidlein Prairie Road, on the west by the Snowbowl Road and the G.A. Pearson Experimental Forest, and on the South by A-1 Mountain.
How: Treatments (hand harvesting, cut-to-length harvesting, and whole-tree mechanized harvesting) include meadow restoration, trail relocation to protect Mexican spotted owls, road management, fire hazard

reduction, restoration of understory vegetation, burning, habitat enhancement, and mistletoe study. A Categorical Exclusion (Category 4) was initially signed at the Regional Office in 1998 and an environmental assessment was distributed in early 1999. Two appeals (July 1999 and October 1999), brought by the Forest Guardians, Flagstaff Activist Network, and the Forest Conservation Council brought a stop to this action on Federal lands. The two main points of the lawsuits (among others) were a State Historic Preservation Office cultural resource technicality and confusion about a 30-day comment period. The latter is not clearly defined by the Forest Service NEPA appeal guidelines. The suit was resolved out of court on June 16, 2000. A second environmental assessment was released July 17, 2000, with a 30-day comment period.

8. Title: Taylor Woods Thinning Study
Landowner: U.S. Forest Service.
Who: Fort Valley Experimental Station, Coconino National Forest working in cooperation with Northern Arizona University, College of Ecosystem Science and Management. Contact: Doc Smith, Ecological Research Institute, 523-7502.
What: At the turn of the century, Taylor Woods was a pasture/meadow. About 1920, after livestock were removed, the site was colonized by ponderosa pine, creating an even age stand. In 1962, small plots with up to 6,000 small trees per acre were thinned to different growth stocking rate levels, for example, 30 to 120 square feet of basal area/acre. Trees are also left with fairly uniform spacing, not in the more typical or natural clumps surrounded by open areas as found in natural sites. Each plot has signs explaining the stocking level to the visitor. Taylor Woods Thinning Study shows that spindly trees can respond with both diameter growth and canopy structure when thinned to uniform basal areas. There is a resultant increase in understory cover, which varies by stocking level. A recent addition to the experiment is burning of half of each basal area plot to compare the growth following thinning and growth following thinning and burning.
When: 1962 to present.
Where: Ca. ¼ mile north of Highway 180 on Snowbowl Road, west of Flagstaff before entering Baderville in the Fort Valley area.
How: Mechanical thinning.

9. Title: G.A. Pearson Natural Area
Landowner: U.S. Forest Service.
Who: Northern Arizona University in cooperation with the Coconino National Forest.
What: Small plots on the G.A. Pearson Natural Area located near Flagstaff, AZ. Contact: T.E. Kolb and W.W. Covington, Ecological Research Institute, 523-7491.
When: 1993 to present.
Where: Gus A. Pearson Natural Area, along U.S. Highway 180, west of Baderville in the Coconino National Forest.
How: In 1993-94, two ecological restoration treatments and a control were implemented in this ponderosa pine site: partial thinning (thinning to create tree density and structure which has all ages tree classes and no prescribed fire), greater thinning (thinning with fewer trees left on site and prescribed fire), and a control (current dense condition with no thinning or prescribed fire). Additional information has been collected in 2000, approximately 5 years after treatments were started. This demonstration plot shows that thinning to pre-settlement conditions can reinvigorate presettlement trees up to 450 years old.

10. Title: Chimney Springs Interval Burn Site
Landowner: U.S. Forest Service.
Who: U.S. Forest Service, Fort Valley Experimental Station. Contact: Walker Thornton, Peaks Ranger District, 527-8215. Work originally conducted by Steve Sackett, now retired. Work now under the direction of Sally Haase, Pacific Southwest Experiment Station, 909-680-1551.
What: This experimental burning project has been conducted for 23 years since 1976. The purpose is to measure the effects of different prescribed fire burn intervals (1 to 10 years) on hectare-sized plots in the ponderosa pine forest. Most of the plots have been burned about three times. Preliminary results suggest that the burns are not killing the pole sized thickets of young "black jack" ponderosa pines but are killing old growth "yellow bellied" ponderosa pines. The slow burning of the deep duff layers at the base of the old growth trees kill the cambial cell layer at the root collar, causing post-fire mortalities.
When: 1976 to present.
Where: West of Flagstaff near Highway 180, east of Fort Valley, to the east of Forest Service Road 164B.

How: Prescribed burning.

11. Title: Woolsey Plot Study
Landowner: U.S. Forest Service.
Who: Northern Arizona University, College of Ecosystem Science and Management. Contact: Margaret Moore, Ecological Research Institute, 523-7457.
What: In 1912, T.S. Woolsey, Jr., Southwest Regional Forester, established about 51 plots in 7 counties in Arizona and New Mexico, within the ponderosa pine type. Plots ranged in size from 72-480 acres, to 2-14 acres, and 50 by 50 meter subpots. The plots were established after grazing and some logging had been conducted, but prior to the 1920 date after which the ponderosa pine seed crop irruption in northern Arizona. A Northern Arizona University graduate student, David W. Huffman, is remeasuring 20 of the 51 plots, under the direction of Dr. Moore. While this is not a forest restoration study per se, it has relevance to forest restoration plots.
When: Resurvey of plots began in 1998.
Where: Apache, Coconino, Gila, and Kaibab Counties in Arizona, and Carson, Cibola, and Santa Fe Counties in New Mexico.
How: Resurvey.

12. Title: Tusayan Ranger District Restoration
Landowner: U.S. Forest Service.
Who: Kaibab National Forest, Tusayan Ranger District in cooperation with Northern Arizona University. Contact: John Brink, Tusayan Ranger District, 635-5642.
What: 80 acre study area established in 1997 as part of the Northern Arizona University Forest Restoration research project. This is also part of the Northern Arizona University research project being conducted in cooperation with Grand Canyon National Park
When: 1997 to present.
Where: Near Grandview Lookout Tower, T30N, R4E, Sections 27 and 28.
How: The project measures overstory tree structure in the ponderosa pine type, tree regeneration, shrubs, herbaceous plants, and woody debris and forest floor material. Treatments (June 1998 to June 1999) included prescribed fire and thinning with a full restoration, minimal thinning, burn only, and control area. Fence constructed around area to prevent cattle from entering project area. Fence to be removed after 3 years. A decision memo (signed 6/22/98) cited a categorical exclusion: “Inventories, research activities, and studies, such as resource inventories and routine data collection when such actions are clearly limited in context and intensity.” Ninety letters were mailed to interested publics and seven responses to the project were received. An estimate for the cost of treatment (service contract, site preparation, marking, administration, and prescribed burn) was about $415 per acre. The cost does not include NEPA costs.

13. Title: Williams Restoration Demonstration Project
Landowner: U.S. Forest Service.
Who: Southwest Forest Alliance (SWFA) in cooperation with the Kaibab National Forest. Contact: Martos Hoffman, SWFA, 774-6514, or www.swfa.org/.
What: Demonstration area of 37 treated acres within a 1,400-acre area with ponderosa pine and Gambel oak. Hand felling and “forwarder” (like a skidder with fat tires and a grapple hook) to remove trees (16 inch dbh cap) from an area where there had been logging at the turn of the century, then in 1960s and 1980-90s. Minimal thinning (about 50% stem density) to removed trees from 30-60 feet from old growth trees, clumpy grouping and matrix of openings in other areas keeping canopy closure of larger trees. Trees less than 5 inches lopped and scattered.
When: 1999 to present.
Where: Located about 8 miles east of Williams, AZ
How: Larger trees removed by salvage contractor at a cost of $285 per acre. Wood sold for firewood and a pallet manufacturing. In fall 2000, a prescribed burn may be applied to burn the residual fuels.

APPENDIX H

GRAND CANYON RANKING CRITERIA FOR EXOTIC VEGETATION AND NOXIOUS WEEDS

One hundred fifty-five exotic plant species are known to exist in Grand Canyon National Park. The species of highest concern based on relative abundance, potential spread, and potential impact are:

Acroptilon repens – Russian knapweed (Restricted noxious weed in Arizona)
Cardaria draba – whitetop, hoary cress (Restricted noxious weed in Arizona)
Conium maculatum – poison hemlock
Linaria dalmatica – Dalmatian toadflax (Restricted noxious weed in Arizona)
Onopardum acanthium – scotch thistle (Restricted noxious weed in Arizona)

In addition, there are 23 other species of high concern based on significance of impact and feasibility of control.

<u>Additional Species of Concern:</u>

Aegilops cylindrica	Jointed goatgrass (Restricted noxious weed in Arizona)
Agrostis stolonifera	Redtop, bentgrass
Bromus tectorum	Cheatgrass
Bromus inermis	Smooth brome
Cenchrus incertus	Field sandbur (Regulated noxious weed in Arizona)
Centaurea maculosa	Spotted knapweed (Restricted noxious weed in Arizona)
Centaurea diffusa	Diffuse knapweed (Restricted noxious weed in Arizona)
Squarrose knapweed	Centaurea virgata
Chondrilla juncea	Rush skeletonweed (Prohibited noxious weed in Arizona)
Conyza canadensis	Horseweed
Convolvulus arvensis	Field bindweed (Restricted noxious weed in Arizona)
Dactylis glomerata	Orchardgrass
Elymus repens	Quackgrass (Restricted noxious weed in Arizona)
Erodium cicutarium	Filaree
Hordeum murinum	Rabbit barley
Marrubium vulgare	Horehound
Poa pratensis	Kentucky bluegrass
Salvia aethiopis	Mediterranean sage
Sonchus asper	Spiny sow-thistle
Sorghum halapense	Johnson grass
Tribulus terrestris	Puncturevine (Regulated noxious weed in Arizona)

Species not yet documented above the rim within Grand Canyon National Park, but spreading on surrounding lands:

Alhagi maurorum	Camelthorn (Restricted noxious weed in Arizona)
Centaurea solstitilis	Yellow star thistle
Cynoglossum officinale	Houndstongue

APPENDIX I
MITIGATION MEASURES

Adapted with permission from Mitigation Measures for East Rim EMA
Soil and Watershed Report by Janet Travis 1/11/96

NOTE: Some mitigation measures may not apply directly to the current work plan, but are included to establish important guidelines and principles. If the experiment is successful, the process may be carried to other areas (i.e. road construction improvement, steeper slopes, presence of meadows and sinkholes, etc.) where some of these mitigation measures are more applicable.

The following measures were developed based on experiences from past management activities performed by the Forest Service where conditions, soils, and mitigation measures were similar and the measures were successful in preventing adverse effects.

A Soil Scientist or Hydrologist will coordinate with other resource specialists to implement Best Management Practices, which are in the Soil and Water Conservation Practices Handbook, and in appendix C of this document.

No new roads or skid trails will be placed in the bottoms or meadows, except for designated skid trails crossing drainages.

Designated drainage's, meadows, and sinkholes will be protected by a 10 meter (33 foot) no-machine-entry zone from the normal high water level in the drainage's, the edge of the meadow, or the break slope of the sinkhole.

Using ROMs, all unnecessary roads will be obliterated or closed. These roads will be scarified or ripped, barricaded, and seeded.

Seed mixtures approved by agency specialists will be used for seeding closed and obliterated roads, skid trails, landings, and any other areas where seeding is required.

For soil protection and nutrient recycling, some slash should be left scattered in all areas where visuals, fire management, and disease are not a factor.

Sinkholes greater than 1/4 acre in size or with side-slopes greater than 25% will have a 10 meter (33 foot) no-machine-entry zone around them and trees will not be harvested in them. Other sinkholes may have trees harvested in them, but the logs will be endlined out. Slash and debris will not be pushed into the sinkholes for disposal.

An agency hydrologist will approve skid trail locations and skidders will be restricted to the skid trails.

Where ground cover and lifter have been removed, skid trails on slopes of 8-25% will be waterbarred approximately every 75 feet and on slopes over 25%, approximately every, 50 feet. All other skid trails will be waterbarred as designated by agency specialists.

Due to the draughty and rocky nature of the soils, containerized stock should be used for plantations.

APPENDIX J
BEST MANAGEMENT PRACTICES (BMPs)

Adapted with permission from Best Management Practices for East Rim EMA
Soil and Watershed Report by Janet Travis, 1/11/96

NOTE: Some BMPs may not apply directly to the current work plan, but are included to establish important guidelines and principles. If the experiment is successful, the process may be carried to other areas (i.e. steeper slopes, presence of meadows, etc.) where some of these BMPs are more applicable.

In order to minimize potential adverse effects, specific Best Management Practices (BMPs) are identified to protect the soil resource and water quality. These practices are based upon the principle that non-point sources of pollution can be most effectively controlled through the implementation of preventative measures.

BMPs were developed through the Integrated Resource Management process as agreed upon by the State of Arizona and the USDA Forest Service Southwestern Region (intergovernmental Agreement Between the State of Arizona and the USDA Forest Service Southwestern Region). The purpose of this agreement is to meet objectives defined by the U.S. Congress as stated in the Federal Water Pollution Control Act as amended in 1987. These objectives are to restore and maintain the chemical, physical and biological integrity of the nation's waters in Arizona by complying with water quality standards identified for designated uses in downstream perennial waters. Unless monitoring proves contrary, implementation of the following BMPs constitutes complying with Arizona State and Federal Water Quality Standards for designated uses in downstream perennial waters. BMPs are designed to minimize plot treatment impacts in all the action alternatives on all soils.

Note: Stream, drainage, and draw are considered synonymous terms.

1. Limit the Operating Season - Limiting ground disturbing activities (tractor skidding, decking, hauling, machine piling, etc.) to dry or frozen conditions will reduce compaction and soil displacement associated with timber harvesting activities when soils are wet or saturated.

2. Use of Study Plot Area Maps for Designating Stream/Drainage Courses for Water Quality Protection - Locations of designated/protected stream courses and filter strips/buffer zones will be shown on the treatment area map. Riparian areas and meadows to be protected are also shown on these area maps.

3. Stream Channel Protection - Drainage channels are to be crossed at designated crossings only. There is to be no skidding or road construction longitudinally within designated stream courses. There will be no decking and machine piling of slash within protected stream courses. Leadout ditches or waterbars, will not be constructed in such a manner as to divert runoff directly into stream courses. Debris generated from timber harvest activities will not be deposited within stream/drainage/draw channels. Trees are to be felled outside the stream channel. Trees, in or on the banks of stream courses, with unexposed root systems that are providing bank and stream charmer stability are not to be removed. Keep at least one stem over l0" diameter every 50' within the filter strip to help slow water flow. The Park Hydrologist will use authority over skid trail and log landing location to protect, as needed, stream courses that were not designated on the sale area map.

4. Streamside Management Zone or SMZ (Buffer Zone Designation) - A standard filter strip/buffer zone will be designated on both sides of designated ephemeral, intermittent, and perennial stream channels, seeps, wet spots, and sinkholes. Activities permitted within the SMZ are limited to directional felling of trees. Vehicles, road construction, machine slash piling and burning of concentrated slash are prohibited within the filter strip/buffer zones. The filter strip/buffer zone may be crossed by skidding equipment at designated crossings only. The edge of the stream/drainage is defined as the normal high water mark.

5. Log Landing Location - Log landings (decking areas) are prohibited in meadows, riparian areas, SMZ'S, and on slopes greater than 25%.

6. Log Landing Erosion Prevention and Control - Immediately after use, landings will be scarified as needed to eliminate compaction and seeded with an approved seed mix.

7. Treatment Plot Design - Cutting areas are to be designed to protect stream courses, and to maintain and improve soil productivity.

8. Use of Terrestrial Ecosystem Survey (TES) - TES was consulted and TES map units were evaluated for suitability for various management practices based on TES map unit properties. Although the TES was intended for soil units mapped in the surrounding National Forest lands, reasonable inferences can be applied to Grand Canyon National Park.

9. Tractor Skidding Design - Skid trails will be designated by agency representatives in conjunction with the restoration team. To minimize soil disturbance by equipment use, trees are to be felled to the lead and end lined to the skid trail on slopes over 25%. Any harvesting of trees within the SMZs will be accomplished by failing to the lead and end lining out of the SMZ. Equipment will not enter the SMZ.

10. Soil Productivity - To maintain or improve soil productivity, manage towards a minimum of 10 tons of slash material per acre in appropriate size classes where feasible (i.e. outside of visual corridors, fuel breaks, etc.). Slash material should be distributed between humus, lifter, small woody (<3 inches in diameter), and large woody components (>3 inches in diameter) with at least 5-7 tons being the large woody components.

11. Slash Treatment In Sensitive Areas - Tractor slash piling will not occur in meadows, streamside management zones (filter strips), riparian areas, and slopes greater than 25%. On slopes greater than 25%, slash will be lopped and scattered. Fire management can designate areas for tractor piling on slopes greater than 25% in areas of excessive fuel loading.

12. Meadow Protection during Treatment Activities - Meadows will be protected to prevent disturbance by skidding, slash piling, etc. through contract clause B6.61.

13. Erosion Control on Skid Trails - Skid trails will be waterbarred, scarified, and seeded as needed, with species designated by the Forest Service. Depressions such as ruts and berms will be filled in and removed, restoring skid trails to the natural grade of the slope where possible. In mixed conifer and fir areas, waterbars are needed on an average of 75 feet on slopes of 1025% and on an average of every 50 feet on slopes over 25%. In pine areas with slopes greater than 25%, waterbars are needed on an average of 100 feet. All other areas will have waterbars placed where the Sale Administrator deems necessary. Slash generated from the timber sale will be spread onto skid trails where designated by the Sale Administrator. Slash should have as much contact with the ground as possible. Align logs and branches across the slope.

14. Soil Loss at Tolerance - In order to prevent soil loss from exceeding soil loss at tolerance, effective vegetative (lifter and plants) ground cover must be maintained. Current soil rates are well within tolerance soil loss rates. Potential soil loss can exceed tolerable soil loss rates on slopes greater than 15% and impair soil productivity as effective vegetative ground cover decreases. The following effective vegetative ground cover (%), after harvest, is required as a minimum in order to prevent soil loss greater than tolerance levels: 0-15% slopes = 10% effective ground cover 16-40% slopes = 40% effective ground cover

15. Road Obliteration - When necessary, roads to be obliterated will be cross-ripped at the road entrance(s) to disguise the road location. Depressions such as berms, ditches, and ruts will be filled as needed to restore to natural contours, cut slopes will be sloped to stable grade, the road surface will be sloped as needed to control

concentrated runoff. Ripping will be to a depth of 4-6 inches. Grade dips will be installed where necessary to reduce concentrated surface runoff and erosion. At the completion of ripping, material from the roadside such as rocks, downed woody material, brush and logging slash will be scattered across the ripped area. The area will be seeded with an approved seed mix. Roads will be signed as "CLOSED".

16. Long Term Road Closures - Closed roads will be reshaped and drainage will be restored. The road will be lightly scarified, seeded with an agency approved seed mix, blocked to traffic, and posted as "CLOSED". Road berms will be removed and ruts will be filled in. Drainage will be maintained and improved to prevent erosion. Where necessary, the entrance will be scarified, seeded, and camouflaged with rocks and slash to improve the road closure.

17. Maintenance of Roads and Erosion Control Structures - Existing and newly constructed roads are maintained throughout the life of the treatment project to insure that drainage structures (culverts, rock crossings, out-sloped drains, etc.) are functioning correctly, and concentrated surface runoff does not occur. Drainage control structures shall receive maintenance prior to winter shutdown of operations.

18. Road Reconstruction and Construction - Drainage structures will be incorporated into each road design. Erosion control practices shall be implemented during construction of new roads and the reconstruction of existing roads. Roads will be constructed with outsloped drains, culverts, and readout ditches to remove water from the roadway. Leadout ditches will be constructed to drain sediment-laden water away from stream channels and drainages. Angle of repose on cut slopes will be 2:1 or less. Cut slopes will be seeded if necessary to prevent erosion. Debris and spoil material generated from road construction activates will not be permitted in stream channels and drainages.

19. Traffic Control During Wet Periods - Hauling is restricted by the agency during wet periods to prevent damage to the road system.

20. Acceptance of Timber Sale Erosion Control Measures Before Timber Sale Closure - The timber sale administrator will verify that the timber sale purchaser has implemented erosion control practices prior to the closure of the timber sale.

21. Machine Piling of Slash - If it is necessary to machine pile slash, minimize disturbance to existing ground cover, surface soil and rock material, and any existing surface organic matter material (i.e. surface litter and duff and old branches and logs). Machine pile when soils are dry or frozen. Leave large pieces of slash in areas deficient of woody debris 3 inches or greater in size. Fuel breaks and visual corridors may be exceptions. Keep slash piles free from soil.

22. Servicing and Refueling Equipment - During servicing or refueling of equipment, pollutants from logging equipment are not allowed to enter any waterway, riparian area, stream course, or the soil. Select service and refueling areas well away from wet areas and surface water, and by using berm around such sites to contain accidental spills. Spill prevention, containment, and counter measures plans are required if the fuel exceeds 660 gallons in a single container or of total storage at a site exceeds 1320 gallons. Agency natural resources specialists will designate the location, size, and allowable uses of service and refueling areas. They will be aware of actions to be taken in case of a solid waste spill. The Park Hydrologist will be notified immediately of any spills. In the event of an accidental spill, the State of Arizona codes for treatment of solid wastes will be followed for clean-up.

MINIMUM REQUIREMENT ANALYSIS WORKSHEET

GRAND CANYON NATIONAL PARK

GRCA (8/2000)

PROPOSED ACTION: Thinning of trees using hand tools in the North Rim proposed wilderness area for the Wildfire Hazard Reduction Research Project.

LEAD PERSON(S): Bob Winfree   WORK UNIT(S): Science Center

PART A: Minimum Requirement: Is this action necessary to manage the area?

1 IS THIS AN EMERGENCY?

YES → ACT ACCORDING TO APPROVED EMERGENCY MINIMUM TOOL CRITERIA

NO → 2

Answer: ☐ Yes ☒ No

Explain:

2 IS THE PROPOSED ACTION ALLOWED BY LEGISLATION, POLICY, OR AN APPROVED MANAGEMENT PLAN

YES → DO ACCORDING TO APPROVED CRITERIA

NO → 3

Answer: ☒ Yes ☐ No

Explain: Although there is no approved criteria, the project funded by line item appropriation by Congress in 1997. The need for this work is described in the Resource Management Plan 1997, pages 108-110 and the Environmental Assessment pages 1-3.

3 CAN THE OBJECTIVES BE ACCOMPLISHED THROUGH AN ACTION OUTSIDE OF WILDERNESS?

YES → DO IT THERE

NO → 4

Answer: ☐ Yes ☒ No

Explain: See the Environmental Assessment summary and alternatives excluded from further consideration (page 18).

4 DOES THIS ACTION CONFLICT WITH LONG-TERM WILDERNESS PLANNING GOALS, OBJECTIVES, OR DESIRED FUTURE RESOURCE CONDITIONS?

YES → DO NOT DO IT

NO → 5

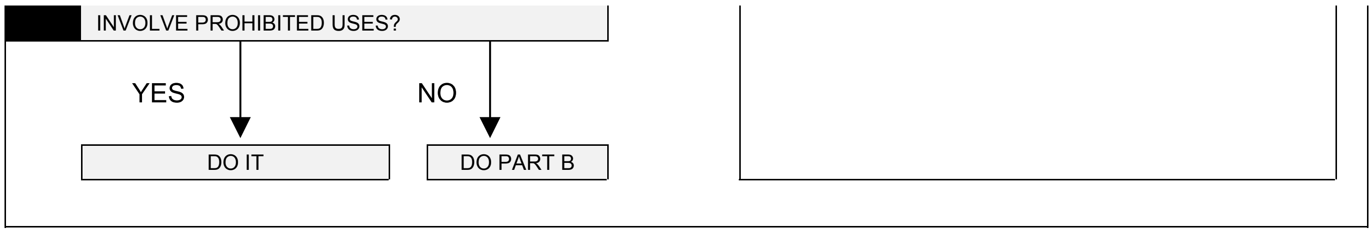
Answer: ☐ Yes ☒ No

Explain: See Resource Management Plan pages 108-112, General Management Plan pages 7-10, Fire Management Plan page 1, and the revised Work Plan pages 6-7.

5 CAN THE OBJECTIVES BE ACCOMPLISHED THROUGH AN ACTION THAT DOES NOT

Answer: ☒ Yes ☐ No

Explain: See the Environmental Assessment pages


INVOLVE PROHIBITED USES?
YES
NO
DO IT
DO PART B